A TREATISE

ON

HYGIENE

AND

PUBLIC HEALTH

EDITED BY

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VOLUME I

NEW YORK
WILLIAM WOOD & COMPANY
1879

Trow's
Printing and Bookbinding Co.,
205–213 *East 12th St.*,
NEW YORK.

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EDITOR'S NOTE.

In the preparation of the scheme announcing a translation of Ziemssen's *Handbuch der speciellen Pathologie und Therapie*, in 1874, it was thought advisable to omit the first volume of the series, that which relates to the subject of public health. This decision was based chiefly upon the fact that the book, though excellent in all other respects, treats the subject almost entirely from a German standpoint, and takes cognizance of a state of things very materially different from that which exists in this country. It was believed, however, that a treatise on private and public hygiene, written with special reference to the different climates, conditions of soil, habitations, modes of life, and laws of the United States, would meet with favor, not only among the subscribers to Ziemssen's Cyclopædia, and physicians generally, but also among all educated classes.

A. H. B.

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INTRODUCTION.

I. PREFATORY REMARKS.

In an introduction to such a subject as Hygiene, it is impossible to be at the same time clear, accurate, and concise, without confining oneself mainly to platitudes, since, in the present state of our knowledge of this subject, almost every general proposition in relation to it requires qualification and the noting of exceptions, and the words "probable," "possible," "perhaps," or "unproved," are called for in almost every sentence. In this particular paper clearness and accuracy have been striven for; but, in order to secure a reasonable degree of conciseness, it has been found necessary to omit reference to a number of topics which might properly have been noticed under this heading.

The fact that many definitions have been given of hygiene, no one of which has proved entirely satisfactory—except, perhaps, to its author—shows that it is one of those terms in the definition of which vague and undefinable words must be used, and also that it is still imperfect and incomplete, thus necessitating a corresponding incompleteness in its description. The usual definition of hygiene as being "the art of preserving health" is defective, since it is more than an art—it aims to increase and improve as well as to preserve; and the word "health" is too vague to be of much value in this connection. To other definitions which have been proposed, we will not refer, noting only that the word is often erroneously used as a synonym for sanitary condition, as when it is said that the hygiene of a place is good or bad. In its broader sense, the study of hygiene includes the examination of the conditions which affect the generation, development, growth and decay of individuals, of nations, and of races, being on its scientific side coextensive with biology in its broadest sense, including sociology, rather than with physiology merely, as some writers state.

Whatever can cause, or help to cause, discomfort, pain, sickness, death, vice, or crime—and whatever has a tendency to avert, destroy, or diminish such causes—are matters of interest to the sanitarian; and the powers of science and the arts, great as they are, are taxed to the uttermost to afford even an approximate solution to the problems with which he is concerned. Of some of these problems indeed, he has only lately begun to suspect the existence, but in doing so he has made a great step in advance, and when they become clearly defined they are in most cases half solved. The old and world-wide belief that disease is due to special Providence, or to the vengeance of offended Deity, although generally abandoned as regards individual cases or limited localities, still lingers in the minds of many with regard to great epidemics, which are thought to be either inevitable, or at least only to be averted by prayer and fasting; but, to the intelligent student, causes and effects do not thus seem to belong to totally different classes, for, although he will admit that there is a close relation between vice and disease, yet he will consider their influence as reciprocal, and that in many cases they are only different names for the same thing.

The hygiene of which this volume is to treat has not so broad a scope as that just hinted at, since the intention has been to produce a practical treatise limited to a consideration of the most usual preventable causes of disease in civilized countries, and more especially in the United States, and of the surest and most economical means of diminishing or destroying these causes.

To what extent the prevention of disease, the prolongation of life, and the improvement of the physical and mental powers in man may be carried, we do not know; but no doubt the tendency of those who write and speak most on this subject is to exaggerate the possibilities of improvement; since it does not seem probable that the conditions of perfect personal and public health are attainable, except in rare and isolated cases, and for comparatively short periods of time; yet, "that the average length of human life may be very much extended, and its physical power greatly augmented; that in every year within this commonwealth thousands of lives are lost which might have been saved; that tens of thousands of cases of sickness occur which might have been prevented; that a vast amount of unnecessarily impaired health and physical debility exists among those not confined by sickness; that these preventable evils require an enormous expenditure and loss of money, and impose upon the people unnumbered and immeasurable calamities, pecuniary, social, physical, mental, and moral, which might be avoided; that means exist within our reach for their mitigation or removal; and that measures for prevention will effect more than remedies for the cure of disease"[1]—will probably be admitted by every one who has carefully studied the subject and made himself familiar with what has been accomplished in certain limited localities.

Sanitary science does not at present possess any well-recognized and satisfactory standard, or norm, by which the condition of health of a given community can be measured, since the death-rate, which is that usually employed, is a very imperfect and unreliable test, as will be here-

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[1] Report of a General Plan for the Promotion of Public and Personal Health, etc., Boston, 1850, 8vo, p. 10.

after explained; but even mortality ratios may serve to give an idea of the importance of the subject.

Mr. Chadwick, from an examination of the mortality in several institutions for the care of orphan children, fixes the normal rate of infantile mortality, under good sanitary conditions, as not exceeding three deaths per thousand annually; and in like manner, from a comparison of the results obtained in prisons, he fixes the norm of mortality for adults of the ages of the prison populations, at the same figure, viz., 3 per 1,000.[1] Elsewhere, he computes the number of deaths from causes clearly ascertained to be preventable, as not less than one hundred and twenty thousand annually in the United Kingdom, and estimates that the serious cases of preventable sickness are more than ten times that number.[2] Another standard, more recently proposed by Dr. Bond, is, that of every 1,000 infants born, there should be alive at the end of the first year 900; at the end of their fifth year, 860; and at the end of their fifteenth year, 830.[3]

Applying these standards to the mortality of the United States for the year ending June 1, 1870, as shown by the census of that date, we find that the total number of deaths reported was 492,263, being at the rate of 12.8 per 1,000, or a little over four times Mr. Chadwick's norm. This number of deaths and its corresponding ratio is known to be too small by probably at least 20 per cent., and the total annual loss of life in this country, from causes well known to be preventable, is certainly over 100,000 annually; while, if we were to consider theoretical possibilities rather than actual probabilities, these figures might be doubled.

In addition to these unnecessary deaths, there are probably one hundred and fifty thousand persons constantly sick in the United States from causes which we have good reason to think are preventable, and we may accept, as a basis for calculation, that the productive efficiency of the average life in this country falls short of the normal amount by at least thirty per cent.

It is an usual estimate among sanitarians, that, by the adoption of proper modes of life on the part of both individuals and communities, nearly one-half of existing diseases might be abolished, and that the annual mortality rate should not exceed 15 per 1,000.

As regards certain localities, and for a limited time, this is no doubt true; but it is worth while to remember one or two facts in this connection. Supposing the birth-rate to remain the same, and the annual mortality to diminish, and omitting the effects of migration, it is clear that this process cannot go on indefinitely, and that within a century the mortality must again increase until it corresponds with the birth-rate.

It is also evident that, as the average duration of life is increased, the liability to disease will also increase, although not in the same ratio. The infants who are now swept away in epidemics of measles or scarla-

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[1] Trans. Nat. Assoc. for the Promotion of Social Science, for 1877, p. 76.

[2] Address before the International Congress of Paris, Aug., 1878.

[3] Sanitary Record, Jan. 24, 1879, p. 57.

tina would, if we could stamp out these diseases, serve to swell the death-rates from other affections, and in this sense it is correct to say that vaccination has increased the number of deaths from diarrhœa or diphtheria, since it preserves some to fall victims from those diseases, who otherwise would have died of small-pox.

The power and wealth of a community depend on the capital accumulated, and upon the proportion which its effective or productive inhabitants bear to those who are non-productive, and the last element is of vastly more importance than the first. In the United States, according to Dr. Jarvis, about one-half are sustainers and one-half dependent; but, as he reckons all persons between the ages of twenty and seventy as sustainers, and apparently makes no deductions on account of sex, criminals, sickness, etc., his estimate is not of much value for our purpose.[1] This distinction between producers and non-producers is, however, an important one to remember in attempting to estimate the loss to a community from preventable diseases. Such estimates are based on the pecuniary value of lives considered as productive or money-earning instruments, or as capitalized investments, and this value varies greatly. Accepting either the calculations of Dr. Jarvis or of Dr. Farr on this point, it can be shown that the direct pecuniary loss to this country on account of preventable sickness and mortality is certainly over $100,000,000 annually, and this without taking into account expenditures incurred on account of sickness, etc., or the unusual losses due to great epidemics, both from waste of life and injury to commerce.

It is evident, therefore, that hygiene is not only a subject of scientific interest to the student or to medical men, but that to the political economist and the legislator its problems and discoveries ought to be of great practical importance—greater, in fact, than many of the subjects with which those gentlemen usually occupy themselves; and, at first sight, it may seem strange that it should not receive more attention and consideration from politicians and legislative bodies than we actually find to be the case. A Standing Committee on Public Health would be about the last committee that either Congress or a State legislature would think of organizing.

But when we examine the amount of knowledge as to the causes of disease which is actually possessed by the immense majority of fairly well educated and intelligent people, and see how much of it is mere vague conjecture, untested theory and baseless estimate, and, above all, how hopelessly unconscious they are of their own ignorance, and how promptly and confidently they will undertake to advise as to what should or should not be done to prevent cholera or yellow fever, or any other disease whatever, we cannot wonder that the public at large is confused by the contradictory assertions made to it, and hesitates as to what should or what can be done in the matter.

There is a German proverb to the effect that "the better is often an

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[1] Political Economy of Health, by Edward Jarvis, M.D.: Fifth Annual Report, State Board of Health of Massachusetts, 1874, p. 336.

enemy to the good," and this often applies to the action taken on propositions for improving the public health. The truly scientific sanitarian will promptly admit that his knowledge is scanty and defective, that he cannot assert that the measures he proposes are the best possible measures, but only that they are the best he can now devise, and that, in the present rapid progress in science and its application for the benefit of mankind, it may be that within a few years at farthest some better means may be found to produce the results desired; and these truthful admissions will often be used as arguments against his propositions and in favor of those of persons much more ignorant, but, by reason of that very ignorance, much more peremptory and assured in their assertions.

The history of the schemes for drainage and sewerage for almost any of our large cities would fully illustrate the delay and inaction which result from this, and the records of disease and death, where available, will show the evil results.[1]

Sanitary measures, to be effective, should be carried out at those times when most people see no special cause for anxiety, and often, therefore, appear to involve unnecessary worry and expense.

When such measures are most successful their value may be least appreciated. "If the expected disease does not appear, the warnings are considered to have been a false alarm, and the precautions taken to have been excessive. The friends of the typhoid fever patient, who will not fail to remember and be grateful for the care and assiduity with which a physican may have treated the disease, would probably have thought him intrusive and troublesome had he taken one-half the same trouble to see that the cause of the fever was prevented."

A man seeks the advice of a physician because he knows, or thinks, that he is sick. The community will do the same under like circumstances; but, how can it be expected to seek hygienic advice so long as it knows nothing of there being any necessity for it? This knowledge can only be obtained by the collection and collation of positive data as to the amount and character of disease prevailing. Mortality statistics are lacking for the greater part of the United States, and where they are furnished, in the majority of cases, the probabilities of error are so great as to render them almost valueless. To the public, such statistics, even if accurate, give little information, since the fact that the annual mortality of a city is 30 per 1,000 has no special significance to the majority of voters. In fact, mortality statistics must be taken in connection with birth-rates and movement of population, to be of much value. In the absence of positive information, the tendency is that each man who does pay attention to the subject feels confident of the truth of his own pet theory, and advocates his special panacea or patent with assertions instead of demonstrations, while, as one after the other of the schemes is tried and found wanting, a general scepticism is developed as to the possibility of finding a remedy.

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[1] See also the account, by Dr. Göttesheim, of the results of deferring the good in hope of the better, in the city of Basel, in Deutsche Vrtljhrschr. f. Oeffentl. Gesundheitspflege, 1877, IX., p. 470.

In the majority of popular works on hygiene, the subject is treated as if it were a very simple matter, and general rules are laid down and sweeping deductions established from entirely insufficient data.

Just as many people suppose that diseases can be treated by their names, and that the study of medicine consists of memorizing certain formulæ for the cure of dyspepsia, neuralgia, pneumonia, etc., so it is thought that if a man can talk about foul and poisonous gases, sewage-contamination, disinfection, and quarantine, he must be a skilled sanitarian.

Imperfect as our knowledge of the causes and means of prevention of disease certainly is, it is still far in advance of the popular practice, because the means of prevention cannot usually be had for nothing.

The mass of mankind are unwilling to sacrifice present comfort or enjoyment for a possible future good, and almost all the dictates of sanitary science call for labor and expense. That this labor often soon becomes in itself a source of pleasure, as for instance in the preservation of personal cleanliness, and that the expense incurred is in most cases the best possible investment of capital, is not and cannot be appreciated by the masses.

One of the best illustrations of the extent to which ignorance and carelessness nullify the utility of advances in knowledge of methods for the prevention of disease is found in the fact that small-pox still appears as a local epidemic, and sometimes with great mortality. If anything is known in preventive medicine, it is that this loathsome disease may be easily and certainly prevented in almost every case, and that it should never appear on the death register; yet, to obtain such an universal and satisfactory vaccination and revaccination of each individual as will give this security, there is necessary the decided and persistent interference of government to an extent which has not yet been provided in this country, except in a few limited localities.

The possible financial results of this carelessness are shown by Dr. Lee in a computation of the cost of the small-pox in 1871–'72 in the city of Philadelphia, which he makes to be $21,848,977.99, while the cost of preventing it is figured at less than $800,000.00. It is true that in his calculations indirect damages figure to an undue extent, and that in his estimate of cost of prevention he provides for but eighteen months; but if we take the pecuniary loss at $10,000,000 only, the annual interest on which at 5 per cent. is $500,000, it is clear that an annual expenditure of $100,000 for the purpose of preventing small-pox only would have been a very good investment for Philadelphia. The question of cost in public hygiene is, however, by no means so simple a matter as this statement would seem to make it.

The burden of sanitary improvements must rest upon property, *i. e.*, "the owners of property are to provide dwellings fit for human habitation, upon sufficient superficial space, with a due supply of wholesome water and with all necessary structural means of preserving health, under penalty for non-fulfilment of obligation; and no sale or tenure of property should be permitted which ignores or violates this principle." (Rumsey.)

But, to carry out proper sanitary plans, either in a house or in a city, often means more than the mere expenditure of money—it means that something must be given up, some luxury or comfort dispensed with. Had the house or city been properly constructed at the commencement, this might not have been the case; but very few habitations, and no cities, have been thus planned. With regard to cities it is almost impossible that they should be so planned, since to effect this would require powers of prediction as to the future size, commercial and manufacturing relations, etc., of the municipality, which cannot be expected in the founders.

Many of the cities in this country are already heavily burdened with debt, for they are less likely to be economical than individuals, and they have spent so much on marble façades and architectural adornments, on civic display, unnecessary officials, and jobs of various kinds, that when the sanitarian comes with his recommendations for new drainage and sewerage works, for a better water-supply, or for a properly constituted and sufficiently paid board of health, he is told that it cannot be done because the city cannot afford it, and upon examination he may find that this is really the case.

Hence, practical sanitarians should keep an eye not only on their own desiderata, but upon all the objects for which the public moneys are expended, to a much greater extent than they usually do; for the proper time to insist that the city needs a good system of sewerage, and a competent board of health, more than it does a new city hall, is before the city hall is authorized and ordered. "There is that scattereth and yet increaseth, and there is that withholdeth more than is meet, but it tendeth to poverty."

It is a very important part of the business of a sanitarian to know what his proposed plans will cost if carried out, both for establishment and maintenance, and the question of expense should have a prominent place in his reports and recommendations: he must show that he is a practical business man as well as a scientist.

Since it is quite proper to distribute the cost of permanent improvements over a term of years, and since sanitary improvements, which are really such, soon pay for themselves, not only in money saved, but in labor spared and distress avoided, it will rarely happen that the plea of poverty and indebtedness can be admitted as a sufficient excuse for permitting well-recognized unsanitary conditions to remain; yet this must sometimes be the case, and then appeal must be made to the State, if the city is worth preserving. There are some cities which it would be cheaper to either abandon, or burn down and commence afresh, than to put them in good hygienic condition, retaining their present levels, streets, sewers, and so forth.

The relations between sociology and hygiene are extremely intimate, a fact which seems not sufficiently appreciated by the students of either subject.

A mode of life whose effects shall be limited to the individual is impossible except in a case like that of Robinson Crusoe before his man Friday joined him, and the well-known analogies between human society and the living human body may be applied here in many ways. As Dr. Geigel points out—communities and nations, like individuals, have their acute and chronic diseases, their fevers and neuroses, their affections of growth and of decay, of infancy and of manhood—and so each race or people, State or city, has its own peculiarities, its constitutional tendencies, which must be taken into account by those who wish to preserve or improve it.

The cholera belongs to the delta of the Ganges, and the yellow fever to the tropics of the New World. The conditions which develop pestilential fevers in one race seem to produce dysentery in another. One city is a stronghold of typhoid fever, and another of erysipelas.[1]

In the United States, if we blindly follow the formulæ which have been found more or less efficacious in England, France, or Germany, the results will probably disappoint us; nor can the sanitary legislation of Massachusetts, Illinois, and Louisiana be fashioned in the same mould with good, or, at all events, with the best results.

As yet a large part of the foundation for a scientific study of the public health of the United States is wanting, since we do not know what is the state of this public health, except in a few localities, and, even in those, very imperfectly. At the present time the most urgent need of sanitary science in this country is an uniform system of registration of the principal diseases, and next to this—that which would be an essential part of it —a similar system of registration of births and deaths.

Such registration is required for two very different purposes. The first is to obtain prompt information of the beginning of the operation of causes injuriously affecting the public health, and to this end scientific accuracy and completeness must be to some extent sacrificed in order to gain time. The second is to obtain reliable information as to how much disease there is, what are its causes, and what is the value of various methods of destroying those causes. This second purpose is largely to be obtained by careful observation of the imperfections and mistakes which will occur in trying to attain the first purpose, and it may be observed that if all possible causes of disease could be promptly discovered and removed, there would be little available material for an investigation into the nature and effects of those causes.

The absence of the information which such registration would give is one of the greatest obstacles to hygienic progress, for it is due to this that our legislators and political economists do not take the hygiene of the people into consideration, except in a few special cases.

On the other hand, those who profess to have made a study of hygiene are too often ignorant and careless of the first principles of legislation, and hence propose absurd or inadequate means for carrying out their schemes of reform and improvement, which not only brings themselves

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[1] "There is no social phenomenon which is not more or less influenced by every other part of the condition of the same society. . . . It follows from this consensus that, unless two societies could be alike in all the circumstances which surround and influence them, no portion of their phenomena will precisely correspond." (Mill).

into contempt, but, which is of much more importance, tends to discredit sanitary science, and to the classification of all its votaries as impracticable, discontented reformers, or as loud-voiced, unscrupulous charlatans, who wish to turn the social edifice upside down, because their own natural place is so near the bottom of it. While it is true that the general principles of hygiene are few and comparatively simple, it by no means follows that the subject is an easy one to comprehend, or that, because a man knows that pure air, water, and food are desirable, he is therefore able to point out the best means of obtaining them. The rules of addition and subtraction might as well be said to include the calculus.

Of late years it is beginning to be understood that the knowledge which should be possessed by the man who is to act as the guardian of the public health, and as the official adviser, in sanitary matters, to the legislative and executive powers of a state or municipality, cannot be comprehended in a few fixed rules or short popular sentences—that every medical man is not necessarily a skilled sanitarian, and that, therefore, differences of opinion among physicians as to the value of sanitary measures do not prove conclusively that we have no positive information on the subject. It is not well to be over-sanguine, but we have reason to hope that the time is at hand when the candidate for the position of a health official will be required to show that he has received a special and sufficient education to fit him for the office. Even now the few who have obtained such an education find no lack of demand for their services, although it is true that the compensation offered is not usually adequate to the time, labor, and money, which must be expended in acquiring such special knowledge.

Among architects, engineers, lawyers, and politicians, a feeling is very common that the sanitarian should confine himself to the pointing out of the evils to be remedied; that he should be a sort of inspector of nuisances, with sufficient knowledge of medicine to give a name to the evil results observed, and that he should leave to them, with their special and superior knowledge, the task of remedying these evils. This plan has been very thoroughly tried, and the results are not satisfactory—in fact, the prevalence of this idea has been one of the causes of the slow progress of hygiene.

A lawyer, an engineer and a physician, each fairly skilled in his profession, and associated as a sanitary board, are by no means equivalent to one man who has had so much training in each of these professions as to be well acquainted with that part of each which has a bearing on hygiene.

As regards so-called practical hygiene, *i. e.*, the prevention of disease, it is evident that we may try to attain this in two very different ways, since we may either attempt to avoid or remove the causes of disease, or to make the body less susceptible to the action of these causes. The latter method has received very little scientific study of late years, and its literature is mainly popular and an echo of precepts which will be found at great length in some of the earliest printed works on medicine. Considering the great number of causes of disease, and the impossibility of shunning them all, even with the greatest care—nay, that this great care, if exercised, becomes itself a cause of disease, as is expressed by the old proverb, "*Medicè vivere est miserè vivere,*"—and, on the other hand, remembering that the power which we have to modify plants and animals by regimen and breeding makes it probable that the human body might in like manner be improved by a sort of hygienic organoplasty, to use the phrase of Royer Collard,[1] it might at first sight appear strange that more attention is not paid to this branch of preventive medicine.

While, however, it is theoretically possible to thus improve the physical condition of the individual, it could not be done without an amount of interference with personal freedom which would probably produce evils much greater than those sought to be avoided, since to be effectual it would be necessary to work in accordance with the laws of natural selection, and prevent the reproduction of weak and unhealthy persons.

The little that can be done in this direction must be effected by parents and teachers; by guiding the children under their charge into proper mental and physical habits; and what these habits should be and how this guiding can be best effected, is one of the most important problems in education—in fact, it is *the* problem.

It is perhaps just as well that few persons appreciate the difficulties and responsibilities of meddling with the child's mental, physical or spiritual nature and of trying to mould these according to some given pattern, for, if the subject were fully understood, very few would venture to do anything at all lest they should do more harm than good.

With this brief sketch of the scope and utility of hygiene, and of some of the obstacles to its progress, we may pass to the consideration and classification of its subject-matter—namely, the causes of disease.

II.—Causes of Disease.

The ancient classification of diseases was either by symptoms, or by the parts of the body affected. Following this, and still very generally prevalent, came the classification by the results produced, *i. e.*, according to pathological anatomy.

Neither of these systems, nor the nosologies or nomenclatures founded on them, are of any special interest or utility to the sanitarian; what he desires is a classification of disease by causes, and although it is not yet possible to furnish this completely or accurately, yet enough is now known of the etiology of disease to permit of a division of its causes in several different ways, each presenting special advantages and disadvantages.

For instance, the causes of disease may be divided into avoidable and unavoidable, the former being classed according to the channels through which they enter or affect the body, as by the respiratory, digestive, cutaneous, genito-urinary, circulatory and nervous systems, corresponding roughly to the subjects of air, food, water, clothing, etc.; while the latter

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[1] Organoplastie hygiénique, ou essai d'hygiène comparée, Mem. Acad. Roy. de Méd., 1843, X., p. 479.

would include heredity, age, sex, and, practically, climate and occupation.

A second useful division of the causes of disease is into those which affect the individual chiefly, and which are to be avoided or removed, if at all, mainly by individual effort, thus pertaining especially to what is known as personal or private hygiene;—and those which affect classes or communities, and require combined effort for their extinction, or, in other words, belong to public hygiene.

Still another convenient classification for our purposes is into, 1st, hereditary; 2d, physical and chemical; 3d, organized or vital; 4th, mental or emotional causes.

Of these the first class belongs largely to the unavoidable causes of disease and to personal hygiene. In so far as these causes affect, or are affected by, races, sufficient data do not yet exist for their discussion; but it is worthy of note that no country in the world affords so promising a field for the study of ethnological health characteristics as the United States, and the little now known on this subject, *e. g.*, the superior average longevity of the Jew, or the comparative immunity of the Negro and the Chinese from yellow fever, is of sufficient interest to warrant careful investigations in this direction. In so far as they affect individuals they are of great importance to the legislator and jurist in relation to insanity, pauperism, and crime, and to the practitioner of medicine a knowledge of them is essential to success ; but, in relation to practical hygiene, the little we have to say about them will be in connection with the jurisprudence of hygiene—in another place.

The second class, *i. e.*, the physical and chemical, will be fully discussed in the special sections of this work.

The fourth class, including the mental and emotional causes of disease, is one of great interest, and presents some of the most difficult problems with which either the physician, the sanitarian, or the legislator has to deal; but in this connection it is impossible to consider them, for it would require a discussion of the whole field of psychology and psychiatry.

The third class of causes, viz., those which are known or supposed to be organized or vital in character, is the most important of all in public hygiene, and hence we shall dwell upon it a little.

Of the total sickness and mortality of the human race, a very large proportion is due to those diseases which may become epidemic, and these are of peculiar and special interest to the sanitarian, not only because of their frequency and the magnitude of their effects, but because it is believed that they are all more or less preventable, and because such prevention requires something more than individual action.

With regard to this word epidemic—as well as to nearly all the terms used in attempts to classify and characterize these affections, such as contagious, infective, zymotic, miasmatic, etc.—there is more or less confusion and ambiguity, and each new writer now usually thinks it necessary to define the sense in which he proposes to use them. The word "epidemic" as used here, means general, prevalent, affecting many people in a community, and as applied to disease it simply indicates its relative prevalence. It is not a cause, but a result;[1] it is not an essential characteristic of a disease, but a character which may be either present or absent. An epidemic disease may or may not be zymotic, endemic, or specific. There is no recognized standard as to what degree of prevalence constitutes an epidemic, nor could the same standard be applied to different diseases, the only attempts to fix such a standard known to the writer being those of Dr. Buchanan, who, in comparing the concurrent prevalence of seven infective diseases, takes for each an annual mortality of 1.2 or more, as entitling the disease to be called epidemic;[2] and of Dr. R. F. Michel, who states that boards of health in the Southern States, where yellow fever is prevalent, are accustomed to consider this disease epidemic when the deaths from it exceed the deaths from all other diseases; and after properly objecting to this rule as arbitrary and unscientific, proposes "to regard a disease as epidemic which has become so prevalent in a population that we meet examples of it more frequently than we meet with cases of any other one form of disease."[3]

The remark of Laënnec, that many diseases not regarded as subject to the influence of the "*constitution médicale*" are much more frequent at certain times than at others, will probably be confirmed by the experience of almost every physician, as, for instance, in relation to cases of organic disease of the brain, heart, kidney, or liver, of malignant growths, and even of special forms of dislocations or fractures; but how far this may be due to chance, or to the reputation of the practitioner, we have no data to determine. The appearance in epidemic form of such diseases as lead-colic, scurvy, etc., is now rare, but the sanitarian should not forget the possibility of their occurrence ; for like causes, under like circumstances, will produce like effects. It is usual for lecturers on sanitary science to claim that the disappearance, not only of these diseases, but of such affections as the plague, the sweating sickness, and leprosy, is due to the superior knowledge and hygienic conditions of modern times; but the simple truth is that we do not know why these last diseases have disappeared or become rare in Europe, nor have we any scientific grounds for thinking that they may not again prevail in an epidemic form in civilized countries—at least, unless we shall succeed in obtaining much more accurate knowledge than we now possess as to the conditions which led to their disappearance.

The most important forms of epidemic diseases in this connection are those which are supposed to be due to specific causes, usually spoken of as poisons, and which are classed by German writers as the infective (not infectious) diseases. In many of these diseases the cause can reproduce itself without limit, presenting thus one of the characteristics of a living thing or organism; and in a few of them this living organism is known,

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[1] Levy: Traité d'Hygiène, 5th ed., Paris, 1869, Vol. II., p. 364.

[2] Trans. Epidem. Soc., Lond., Vol. III., Part II., 1873, p. 405.

[2] Epidemic of yellow fever in Montgomery, Ala., Trans. Med. Ass'n State of Alabama, Twenty-seventh Session, 1874, p. 111.

forming the class of parasitic diseases. Following the usual modern classification, we may divide the infective diseases into:

A. Parasitic diseases.
B. Contagium diseases.
C. Miasmatico-contagium diseases.
D. Miasmatic diseases.

That the cause of each of the three first classes is specific is inferred from the fact that the disease transmitted is always the same disease. Trichinæ never produce hydatids; the bacillus anthracis communicates only splenic fever; small-pox never changes into measles, nor cholera into yellow fever. There is no satisfactory evidence that any of these causes ever arise spontaneously; in every case the pre-existence of the specific poison or organism is necessary.

In the majority of parasitic diseases we can recognize the causal organism apart from the disease which it produces, but this is not the case with the other classes; in fact, as soon as we learn clearly the nature and life-habits of an organism causing disease and its mode of propagation, whether within or without the body, we consider that disease as a parasitic disease. Very probably some of the diseases now known only as contagium or miasmatico-contagium will in future be transferred to the parasitic class, and this probability is expressed by what is known as the germ theory.

To understand the controversies which have arisen on this point, correct views of which are not only of theoretical interest, but of very great practical importance to the sanitarian, it is necessary to know something of the nomenclature of the subject, which has become very confused and unsatisfactory, since the words bacteria, microzymes, germs, contagium, etc., are used by different authors, and by the same author, at different times, in different senses, and to this is due much of the disagreement which exists.

That some diseases are due to the entrance of living organisms into the body is a very old theory, first set forth with some attempt at precision after the discoveries of Leeuwenhoeck were published. The history of the various speculations based on this theory, and on that of fermentations, is a curious and interesting one, but would be out of place here; and it need only be said that the views now held by the majority of physicians date only from the cholera epidemics of 1832 and 1849, and that they had no scientific precision prior to the well-known researches of Pasteur into the processes of fermentation and putrefaction and the minute organisms connected with them.

In almost all fresh water, in dead and decomposing organic matter under ordinary conditions, and throughout the lower strata of the atmosphere, we find, upon examination with the highest powers of the microscope, myriads of minute bodies which have the power of self-propagation when supplied with a suitable nutritive material, and some of which exhibit motions in certain stages of development, in such a manner that we must class them as living things. For these, as a class, we have no good comprehensive term, since neither animalculæ, infusoria, microzymes, microphytes, nor microzoa are sufficiently comprehensive, and it is necessary to coin some such word as microdemes—little living bodies—to express what is meant. The term bacteria is sometimes, though by no means always, used in this sense, and the term microzyme, as used by Dr. Burdon Sanderson, is almost exactly equivalent to microdemes, but, as used by its originator, Bechamp, it has a much more specialized meaning.

Even if the word bacteria be used, in its broadest sense, as equivalent to the French phrase "les bactéries," it will not be sufficient to express what we desire. As defined by modern French botanists, the bacteria are cells not containing chlorophyll, which may be globular, ovoid, cylindrical or spiral in form, reproducing by fission, isolated or in groups. This includes the forms formerly supposed to be distinct genera known as bacterium, vibrio, and spirillum, but it cannot, without a violent assumption, be made to include the contagium particles of vaccine, or many other minute forms which are liable to appear. The word microdeme will, therefore, be employed here in the sense of a minute living particle or organism, whether it be animal or vegetable, and whether it be capable of independent growth and reproduction or not.

Mingled with the microdemes, and sometimes only to be distinguished from them with great difficulty, will often be found other particles, either inorganic or fragments of dead and disintegrating organic matter. When it is remembered that these particles are often so minute as to be only just within the limits of visibility of the most powerful microscope, and that some forms are probably invisible with the highest powers, the difficulty alluded to will be better appreciated. Morphologically, in fact, we have only the three criteria mentioned by Naegeli as characterizing his group of the *Spaltpilze*, namely:

I. The uniform size and minuteness of the granules.

II. Their independent motion, in estimating which great care must be taken to distinguish it from the Brownian movement or from that produced by currents; and

III. Signs of growth and reproductive division of the granules, as shown by their being found in pairs, forming dumb-bells or figures of eight, etc.

The minutest spherical forms of these microdemes are sometimes called micrococcus, while the rod-like forms are what English and American observers usually call bacteria—a word which it is better to avoid, since it probably is applied properly only to one stage of development of certain microdemes, which stage may be described as bacteroid. All of the microdemes which belong, according to the usual classifications, to the vegetable kingdom—the microphytes properly so-called—are classed between the algæ and the fungi, forming the "schizomycetes" of De Bary, the "Spaltpilze" of Naegeli. Billroth, from his researches upon the ordinary forms, concludes that they all belong to one species—the Coccobacteria septica—and he classes them roughly by size and form into

Micrococcus and Microbacteria, Mesococcus and Mesobacteria, and Megacoccus and Megabacteria, which is essentially the plan of Hoffmann.

The work of Naegeli, "Die niederen Pilze in ihren Beziehungen zu den Infectionskrankheiten und der Gesundheitspflege," München, 1877, 8vo, is perhaps the most recent systematic work upon this class of organisms considered as causes of disease; but the reader is advised to preserve a healthy scepticism with regard to many of its statements, and some of the reasons for this will perhaps appear from the references which we shall have occasion to make to it.

The microdemes are spoken of by many as organisms or germs, but these terms are usually understood to imply entirely independent life, and as being inapplicable to such living things as a blood-corpuscle or an epithelial cell.

There is, at present, no evidence worthy of consideration that these microdemes are ever spontaneously generated, or arise from any source other than living organisms, which, however, may assume other forms, and be of very diverse characters. The spores of some of the ascigerous fungi, as, for instance, of several of the valsæ, and also the spores or spermatia of many of the coniomycetous forms, the moving granules set free in certain stages of reproduction in many of the algæ, and in some mosses and lichens, and certain stages of development of some of the microzoa or ciliated infusoria, all come under the head of microdemes, and can scarcely be distinguished, except by a knowledge of their origin or by tracing their development.

Some of them may develop into larger and more complex forms, but of many we have no good evidence as to any special change beyond that of simple multiplication and self-division into similar bodies.

In particular, there is no satisfactory proof that those forms connected with the process of putrefaction ever develop into higher forms of fungi, although this is by no means to be considered as a settled question; and there are some good authorities who believe that at all events the reverse of this process may occur—that is, that certain hyphomycetous forms, such as aspergillus or penicillium, may, under certain circumstances, develop schizomycetous forms of ferments.

Neither aspergillus nor penicillium, however, have any generic value; they are simply transition forms of certain ascigerous or other more highly differentiated fungi, and, as yet, we must be very slow to accept any statements either affirming or denying their transformations.

Not only are some microdemes found in decomposing organic matter, but they usually take an active part in producing or promoting the decomposition; and since organic substances vary greatly in composition, while the products of their decomposition likewise vary, it is a question whether this difference in result depends upon the original composition of the matter, or upon a difference in the microdemes, producing a different mode of action. Naegeli, speaking of the schizomycetes only, thinks, with Billroth, that there is but one species, and that the difference in product depends on the composition and peculiarities of the matter to be decomposed. Cohn, on the other hand, thinks that there are many genera and species of these schizomycetes, each with peculiar powers; but, even if this be admitted, it is uncertain whether a given species developing in two very different substances would or would not give very different results.

The weight of opinion at present is to the effect that there are many different kinds of schizomycetes, that each can propagate only its own kind within a limited period of time (excluding thus possible changes by evolution and natural selection), and produce only certain results.

This, however, is merely an opinion, and only those who have studied the minute fungi sufficiently to gain a moderate knowledge of the difficulties which their many transformations involve can appreciate the nature of the evidence which would be required to prove its truth or falsity.[1]

In the last few sentences we have been speaking of the microdemes as if they were all minute fungi or schizomycetes. This is the usual assumption of writers on this subject with regard to such forms, but it is not only unproved, but very improbable. Whether the bacteroidal forms should be classed with animals, as Dr. Burdon Sanderson thinks, or with the fungi, as Cohn, Naegeli, De Bary, and other botanists propose, is a question of nomenclature of small importance in the present connection; but, to assume that all microdemes are minute fungi, as is done by many of those who call them germs or organisms, is a serious error.

The remarks made above as to the use of the word "organism" apply equally to the word germ. The so-called germ theory of disease is "that many diseases are due to the presence and propagation in the system of minute organisms having no part or share in its normal economy."

Here the words germ and organism are used in the ordinary sense, and if the word "some" be substituted for "many" in the above definition, there are probably few who would not admit the truth of the proposition.

But by many writers on the germ theory all microdemes are considered as germs, and all germs as belonging to the minute fungi, neither of which propositions can be admitted.

There is a marked difference between a germ which originates external to the body and a germ which is simply a particle or cell forming or having formed a part of the body itself, and this distinction should be marked in language as it is in fact. In order to illustrate this we will consider briefly the phenomena of two diseases in which the probability of their causation by germs or organisms is so great as to demand the careful attention and full comprehension of those who are interested in their pre-

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[1] Consult in this connection Les Bactéries: Thèse du Concours par A. Magnin, Paris, 1878, 8vo. In this will be found a very clear and compendious description of the various systems of classification which have been proposed, and at the end is a good bibliography. See, also, "Ueber die morphologische Einheit der Spaltpilze und über Naegeli's Anfassungstheorie," von Prof. F. Cohn, in Deutsche med. Wchnschr., Feb. 15, 1879, in which the results of many experiments are summed up as being completely adverse to the statements of Naegeli.

vention, and which therefore should, provisionally at least, be classed among the parasitic diseases. The first of these is splenic fever, the *Milzbrand* of the German, the *charbon* of the French, better known in this country by the name of one of its special symptoms, viz., malignant pustule.

In the blood and fluids of animals and men affected with this disease are found peculiar bacteroid microdemes, named bacteridia by Davaine, the presence of which was known over twenty years ago, but which did not seem to explain the peculiarities of origin of the disease, since the contagious properties of the blood soon disappeared, although the cause of the disease seemed to cling with great tenacity to certain limited localities, as, for instance, to a particular stable, where it would reappear after intervals of several years.

The explanation of this was at last given by Koch, and his experimental demonstration is a model for investigations of this kind. He cultivated the suspected organisms in fluids apart from the animal body, observed their growth and development into threads, and the formation of certain peculiar bodies or spores in their threads, and from the spores thus developed and from forms obtained from them he produced the specific disease anew in a living animal. It was found that the bacteroidal forms observed in the blood usually died in a few days, but that the spores retain their vitality for at least four years, which explained the peculiar localized persistence of the contagium above referred to. It is especially noteworthy that the *bacillus anthracis*, as it was named by Koch, could only be distinguished, as far as mere inspection goes, from another species, *bacillus subtilis*, by the fact that the first is motionless, while the latter moves. Dr. Ewart finds that B. anthracis is at times, though rarely, a moving organism, the mobile stage appearing at irregular intervals and under circumstances not well understood.[1] But bacillus subtilis is a very common, and, so far as is known, harmless form, and the question as to the possible or probable connection between the two is one of great interest from several points of view. It is very difficult to explain the peculiarity of sudden outbreaks of charbon in cattle over-fed, but this difficulty would be greatly lessened if it could be shown that the harmless, active bacillus subtilis might, under certain circumstances changing the composition of the fluids in which it entered, become the motionless, deadly B. anthracis.

Closely analogous to the cause of charbon appears to be that of an infectious disease of hogs, known as the hog-plague, typhoid fever of the pig, mal rouge, etc. This discovery is due to Dr. E. Klein, who names the disease "infectious pneumo-enteritis."[2] Following the methods of Koch,

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[1] See Quar. Jour. Mic. Soc., April, 1878, p. 161; also Proc. Roy. Soc., 1878, No. 188, p. 464.

[2] Experimental Contribution to the Etiology of Infectious Diseases, Proc. Roy. Soc., 1878, No. 185, p. 101, and Report on Infectious Pneumo-Enteritis of the Pig, Rept. Med. Officer Local Govt. Board for 1877, Lond., 1878, 8vo, p. 169. The methods used in this investigation should be carefully studied.

Dr. Klein succeeded in cultivating in fluids outside the living animal, and in observing the various stages of development of the microphyte which has the power of causing this disease. From his researches it seems that this microphyte is also a bacillus, more delicate than B. anthracis, but which has a moving stage like B. subtilis, and produces spores and filaments like the other species.

Like charbon, the disease can be transmitted to mice or rabbits, but with more difficulty. There are marked differences between the two diseases as regards period of incubation and the pathological anatomy, the most prominent being that "in anthrax or splenic fever the blood of any organ, and especially the spleen, is crowded with the bacillus anthracis; in pneumo-enteritis we have been unable to find anything analogous." As yet we do not know that the disease can be communicated to man. It is highly desirable that the contagious pleuro-pneumonia of cattle, and the so-called Spanish or Texas cattle fever, should be investigated in the same way; and there are special reasons for thinking that the latter disease may be due to a microphyte of a similar character.

In relapsing fever, the history of the peculiar organisms found in the blood has been carefully worked out by Dr. Heydenreich and others, and although the demonstration is by no means as conclusive as in the case of splenic fever, since the spores were not traced, yet the fact that the cause of the disease either actually is, or is closely associated with, the organism *Spirochœte Obermeieri* of Cohn, seems to have been clearly made out.

The spirilla are found only in the blood, and the blood only is infective; they disappear in the stage of remission and reappear before the paroxysm, which may thus be predicted; and the blood seems to be infective during the paroxysm only. If the disease is due to the spirochæte, it evidently has a stage of development which has not yet been traced.[1] In both splenic and relapsing fever the microphyte seems to have specific properties, but the most expert microscopist cannot distinguish it morphologically from similar, but harmless organisms, and it is only by the test of inoculation and the production of the specific disease that they are identified and given specific names.

Yet the relations of the one disease to plethora and of the other to famine are such that we must hesitate to declare their parasites true species, even in the Darwinian sense; and the facts with regard to septicæmia, presently to be referred to, point still more strongly to the conclusion that a microphyte, harmless under ordinary circumstances, may under others become either the producer or carrier of a deadly poison.

With this class of diseases some observers, such as Oertel, Klebs, and others, would rank diphtheria. The most precise statements on this point are to be found in the abstract of a paper by J. C. Ewart and G. A. M. Simpson, presented to the British Medical Association in August, 1878.[2]

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[1] Consult Notes on the Spirillum Fever of Bombay, 1877, by H. V. Carter, Med. Chir. Trans., 1878, LXI., p. 273.

[2] Brit. Med. Jour., Sept. 7, 1878, p. 367.

These observers claim that the microphyte of diphtheria exists in the form of exceedingly minute spores, which in a suitable medium will germinate into long, exceedingly fine rods or bacilli, the life history being much the same as that of bacillus anthracis; and it is claimed that when the spores are applied to a raw surface they rapidly lead to the formation of a diphtheritic membrane.

On the other hand, the researches of Drs. E. Curtis and T. E. Satterthwaite, of New York,[1] led them to conclude that inoculation of diphtheritic membranes on rabbits produce no effects that are not also obtained by inoculation of scrapings from the human tongue, or putrescent fluids.

At present the question of the etiology of diphtheria must be considered as *sub judice*, with enough probability in favor of the germ theory to warrant, on the part of the practical sanitarian, such measures of prevention as would probably be most efficacious if this theory were correct.

With the phenomena presented by the diseases which are accompanied, and may be caused, by the presence of microphytes in the blood, let us compare those presented by the variolous group, which may be taken as a type of the contagium diseases. It is now believed that the means by which these are propagated—their "contagium"—consists of extremely minute transparent particles, neither soluble in water nor in watery liquids, and not capable, without losing its properties, of assuming the form of vapor.[2] In vaccine virus the power to transmit the specific disease is lost after exposure to a heat of about 140° F., but it is not injured by intense cold. The minute particles constituting the contagium come under our definition of microdemes, but there is no evidence whatever that they can multiply or in any way reproduce themselves outside the living body, or that they can be classed with the schizomycetes or other forms of microphytes. The development of bacteroid forms in the fluids containing these particles is coincident with a diminution or destruction of their special contagious qualities.

In scarlatina and measles the contagium has not been isolated as in small-pox, but it is believed to be also particulate and incapable of reproduction outside the body, and this constitutes the characteristic of the contagium group of diseases. To this group is especially applicable the bioplast or graft theory, which is as follows:

"Growth is a molecular change—a particle of animal matter growing or capable of growth (bioplasm) may be separated from its connections and continue to grow elsewhere; it will grow normally if it be normal, abnormally if abnormal; hence, particles of diseased bodies may carry on, in new bodies to which they are introduced, the diseased processes which

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[1] Report of Investigations into the Pathogeny of Diphtheria, made to the Board of Health of New York, N. Y., 1878, 8vo.

[2] Braidwood and Vacher: Second Contribution to the Life History of Contagium, London, 1871, p. 1.

they had taken part in previously." (Brit. and For. M.-Chir. Rev., 1873, LII., 298.)[1]

Another mode of viewing contagium is that of Dr. Dougall, who does not regard contagious units as vitalized entities, but simply as fragments of dead organic matter whose elementary particles are in some occult state of chemical union and capable of imparting their condition to other bodies susceptible of the same change,[2] which, however, seems to be merely a verbal distinction. At all events, as Mr. Hutchinson remarks, there is a strong distinction between a germ which can be got only without the body and a germ in the sense of a cell—a part of the person's organism; and if the word germ is to be applied to the cause of splenic fever, some other term should be used for that of small-pox. A peculiarity of the specific contagium fevers is that they usually affect the same person but once, and in case of vaccine there is evidence to show that this is connected with the presence of the vaccine cicatrix—since in cases where the limb containing the cicatrix has been removed the person has again become susceptible.[3]

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[1] "The quantity of matter in which any molecular change or group of changes is taking place may diminish to a very small amount without the continuity of action being broken. A conflagration may diminish to a spark, and yet spread again to as great an extent as before. A species might diminish to one or two individuals without becoming extinct; and, at the point at which new individuals commence, the molecular actions are often confined to a minute quantity of substance. . . . .

"The material cause of every communicable disease resembles a species of living being in this, that both one and the other depend on, and in fact consist of, a series of continuous molecular changes occurring in suitable materials. The organized matter, as we must presume it to be, which induces the symptoms of a communicated disease, except in the case of the entozoa, can hardly ever be separately distinguished, like the individuals of a species of plant or animal; but we know that this organized matter possesses one great characteristic of plants and animals—that of increasing and multiplying its own kind.* In the instances of syphilis, small-pox, and vaccinia, we have physical proof of this increase, and in other diseases the evidence is not less conclusive.

"The molecular changes taking place in the materies morbi of some diseases resemble the changes in many living beings in another respect also; they permit of being suspended under certain circumstances, and recommence at the point at which they ceased. Thus, the matter of variola and of vaccinia can be carried, in the dry state, to distant parts of the world without injury, like the seeds of a plant."

(*From* Continuous Molecular Changes, etc., by John Snow, etc., London, 1853, pp. 9 and 14.)

[2] Brit. Med. Jour., April 24, 1875, p. 558.

[3] The following case is reported to me by Dr. Robert Fletcher, late surgeon U. S. Vols., who personally observed the facts, and whose statement is absolutely to be relied on.

"During the late war, a soldier was admitted into one of the hospitals in Nashville, for a gunshot wound of the tibia. The vaccine cicatrix was very noticeable above the ankle, where, *more Germanorum*, the operation had been performed. The leg was amputated, and while convalescent the man was attacked with small-pox and sent to the hospital, where the disease manifested itself in the usual manner, and the patient died."

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* See a paper by Mr. Grove, of Wandsworth, Med. Times, Vol. XXIV., p. 640.

The ancient belief that neither contagion, filth, nor meteorological conditions, whether taken singly or together, will account for the great differences observed in the origin and progress of epidemic diseases, and that some unknown cause, such as indicated by the phrase "Epidemic Constitution," must be assumed in order to account for all the phenomena, is still held by some writers. Thus Dr. Ransome, from a study of the statistics of disease in four large towns in England, concludes that such an epidemic influence is the only means of accounting for the correspondence observed between the curves of different epidemics at these points,[1] and Dr. Lawson has more recently reaffirmed the same opinion,[2] which corresponds to his theory of pandemic waves connected with variations in the earth's magnetism. For instance, in the epidemic of small-pox of 1869–'73, which spread over the world, there was a special malignancy, as shown by its spread in places where usually it is confined to a few, and by the unusual number of hæmorrhagic and fatal cases, which seems very difficult to account for by a simple contagion.

But, on taking into account the accumulation of susceptible or epinosic individuals in the intervals of epidemics, and the rapid increase of the probability of epidemic invasion with increase of the epinosic element, the ratio being $p=2x$, where p is the probability and x the number of epinosic individuals,[3] it is evident that the wave phenomena of such diseases may be to a great extent thus accounted for, while the study of the special epidemic just referred to, made by Dr. Léon Colin, makes it probable that the special virulence was acquired in Brittany in 1869, much in the same way as septic poison may be developed, as will be presently explained, so

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[1] Brit. Med. Jour., 1862, II., 386.

[2] Ibid., 1874, I., 482.

[3] De Chaumont: Lectures on State Medicine, London, 1875, p. 172. The mode of calculation employed by Dr. Farr in determining the state of epidemic progression is thus described by Dr. Evans: "Take nine weeks of the early course of the epidemic in three groups of three weeks each; find the average deaths per week in each group; find the number by which you must multiply the first average to obtain the second, and the numbers by which you must multiply the second average to obtain the third; or, as a simpler process, take the difference between the logarithms of the first and second averages, and between the logarithms of the second and third. The first of these differences may be called S^1, and the difference between these two differences, which should, to bear out this theory, be a negative quantity, may be called S^2. We have now the data for constructing the series. The average of the first three weeks is the starting-point and represents the centre week of those three. The next number in the series is obtained by adding to the logarithm of our first number, a number composed of $\frac{S^1}{3}-\frac{S^2}{9}$ remembering that S^2 is a negative quantity; we continue to add to the logarithm for each place in the series a number gradually diminished by the addition in each place of $\frac{S^2}{9}$; after a time the number to be added becomes a negative, and the series gradually diminishes.

This method of calculation can only produce a satisfactory result when an epidemic is increasing with a gradually decreasing ratio of increase. Practitioner, Vol. XIV., London, 1875, pp. 308–9.

that there is no necessity of assuming an "Epidemic Constitution" to explain such phenomena. In those diseases to which the germ theory is more properly applicable, such as cholera or yellow fever, it is possible that the polymorphism of the germ may explain some of the differences observed in the epidemicity of such affections.

From the parasitic blood diseases as typified by splenic fever, and the contagium diseases as typified by scarlatina, we may pass to an intermediate group in which the disease seems due to a poison produced by microphytes, but in which the production does not occur, or at least does not usually occur, within the body. Of these there are two forms. The first is of great importance, in part because it occurs everywhere and at all times, constituting an ever-present danger, especially in surgical and puerperal cases; in part because we now have good reason to believe that it can be prevented in the great majority of instances. This is septicæmia. The use of the terms septic poison, septic bacteria, septic infusoria, etc., is somewhat confusing as found in modern literature. Septic by many writers is used to mean belonging to, or connected with, putrefaction, and by septic bacteria are meant those microdemes which are found in putrefying fluids. Such microdemes may or may not be capable of causing the fever and embolic phenomena characteristic of septicæmia.[1] It cannot be too clearly understood that there are many kinds of microdemes, that a bacterium is simply one form of many microdemes, and that to assert that a disease is due to bacteria is to assert only that the disease is due to some kind of microdeme at that stage of its development when it is a rod. The words bacterium and bacteria should be abandoned to popular literature. As rapidly as we are able to find distinguishing characteristics for classes in these minute bodies, let them be labelled with distinctive names, but let it not be supposed that the name of bacteria implies any identification or classification. For instance, if one says that bacteria are the sole causes of putrefaction, I must deny it, for I have seen putrefaction in the absence of bacteria, but I have never seen it in the absence of microdemes. Septicæmia, as defined by Dr. Burdon Sanderson, is "a constitutional disorder of limited duration, produced by the entrance into the blood-stream of a certain quantity of septic material." This septic poison may be separated from putrefying material by chemical processes, and obtained in the form of a transparent fluid. This fluid contains no germs in the sense that a germ is that which produces an organism, but it does contain a specific, virulent something which can be separated from it by a porcelain filter, and which does not multiply and reproduce itself. The sepsin is not then the cause, but the result, of putrefaction, and when introduced into the living body

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[1] By some writers, as, for instance, Dr. Southey (lecture on Hygiene, Lancet, Nov. 23, 1870), the term zymotic is limited to those diseases which, as a rule, affect the same person but once, while those which do not confer such immunity are termed septic. This, however, would make cholera and ague septic diseases, which is not in accordance with the usual use of that word.

its effects are in proportion to the quantity introduced, like those of a chemical poison.

To produce this peculiar poison within the organism itself—to ensure that there shall be constant additions of it to the blood-stream—it seems highly probable that the action of microphytes is always necessary, and hence septicæmia may be in one sense said to be always due to microphytes, which last may produce the specific poison either within or without the body.

It is not, however, true, that all the microphytes which seem to have the power of producing putrefaction can do so in the living body, or rather in contact with living tissues ; nor does it follow by any means that when a portion of the living body dies and putrefies septic products always pass into the blood-stream. In the intestinal canal, and in the air-passages, there are at all times multitudes of microdemes, some of which have the power of causing putrefaction under favorable circumstances, but which do not do so in us in health. In order that the microdeme may become the starting-point of the septic or pyæmic process in the living organism, it seems necessary that it shall have been derived from, or come in contact with, some specific source of contagion, or else—but such cases are certainly the minority—that the condition of some part of the living body shall have been so far changed from its normal vitality that the microdeme can flourish in it as in dead organic matter. In either case, in addition to the growth of microphytes and the production of their specific products, it is necessary to the production of the septic phenomena that the condition of the tissues and vessels shall be such as to permit the entrance of the septic poison into the blood.

Hence, two methods of prevention of blood-poisoning after surgical operations have given good results, the first being the well-known method of Lister, with its many modifications, which aims at totally preventing the contact of living microphytes with the injured surface; the second, being the air-dressing, which aims at the freest possible exposure, in order that the dead and septic matters may easily and rapidly escape. So long as only the ordinary microdemes of all air and water are present, the difference between the results obtained by these apparently opposite methods is not great; but so soon as the element of specific contagium comes in, the only hope of safety lies in the absolute exclusion. Dr. Sanderson has also shown that while the property of producing the septic poison is not possessed by the ordinary bacteroid forms, or at least not to a marked degree, it may easily be developed in great potency by the injection of fluids containing these forms into the peritoneal cavity of the guinea-pig, reinjecting the effused fluids thus produced into a second animal, and so on, each successive production of fluid increasing in its power of producing rapid septic poisoning. The analogy between this and the development of special malignancy in the contagium diseases has been already alluded to, and it is possible that a similar relation may exist between bacillus subtilis and b. anthracis.

We have next briefly to refer to those forms of disease classed as miasmatic, in which the poison is developed outside the body. Taking the malarial fevers as a type, it may be said that the prevailing opinion is that they are due to a specific poison usually produced in decaying vegetable matters. The latest announcement of the discovery of the microphyte causing this disease is made by A. F. Eklund, Surgeon of the Royal Swedish Marine, who claims to have discovered in the blood and urine of those thus affected a peculiar organism known as the Lymnophysalis hyalina.[1] This requires confirmation very much. The most important fact to the practical sanitarian, in regard to this class of diseases, is their usual, though not invariable, connection with soil moisture, and the fact that thorough drainage is a powerful means of preventing them.

The last class of diseases is that called the miasmatic contagious, in which it is supposed that the specific cause of the disease does not multiply as such in the body, but comes from without, having been developed in a peculiar way. Of this class cholera and yellow fever may be taken as types.

Naegeli, assuming that such diseases are due to microphytes, indicates two possible explanations: 1. The microphyte from the sick person must, before it can produce the disease, pass a special stage of development in an abnormal substratum. This he calls the monoblastic theory. 2. The abnormal substratum produces a miasm, without which the microphyte produces no specific effects, which is the diblastic theory. As he considers all contagion to be due to schizomycetes or *Spaltpilze*, and does not admit that there are many kinds of these organisms, he is forced to accept the diblastic theory, and supposes that the contagium of small-pox is a compound of a microphyte with peculiar products of decomposition (*Krankheitsstoff*), which simply removes the difficulty one step. This corresponds to Pettenkoffer's formula, that if $x =$ the germ, $y =$ the substratum, and $z =$ the specific poison, then $x + y = z$; but Pettenkoffer does not affirm that there is but one kind of germ. With regard to the monoblastic theory, there seems no necessity for assuming that the external substratum of development must be abnormal or peculiar. If the parasite has two or more stages of development, analogous to the metamorphosis of a mosquito or of the filaria sanguinis—if in stage x it only flourishes in the living body, and in stage y only in dead organic matter—and if it is only in stage y that it is reproductive or communicable, there seems nothing impossible in the theory. The analogy to the known parasitic diseases is close;—since these also, as pointed out by Dr. Manson, may be divided into those which are directly contagious, such as scabies, and those indirectly contagious, such as hydatids or filaria; and the phenomena of the indirectly contagious diseases are that they are endemic in certain localities, they may be imported into other localities, they disappear with the medium of development, are not infectious, inoculable, nor hereditary, but are found to prevail in certain families.[2] Whatever explanation, if any,

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[1] Arch. de méd. navale, July, 1878.

[2] P. Manson on Filaria Disease: China Customs Med. Reports, Sept. 30, 1878, p. 15.

be acceptable, the question as to whether an external substratum of decomposing organic matter is necessary to the spread of a disease, is one of the greatest interest and importance to the sanitarian. Where no such substratum is necessary, as for instance, in scarlatina, the only resource in his power to check the spread of the disease is the isolation of those affected by it and the disinfection of their persons, clothing, bedding, etc. His object is to destroy or prevent the reproduction of the specific microdemes or their specific products, and, in the present state of therapeutical knowledge, this can only be done at the time when they are external to the living body, that is to say, at the very time when he has no means of recognizing their presence.

But if they must pass a stage of development in some external substratum, then, if he can either secure the absence of that substratum or make it unfit to promote the development of the microdemes, he can check the spread of the disease.

The nature of the most usual substratum is indicated in the conclusion of Dr. Curtis, that "*localized filth accompanied with moisture* constitutes *the great source of excessive disease and death.*"[1] The italics are in the original. The same fact was strongly insisted on by Mr. Simon in his report on "Filth Diseases and their Prevention," presented to the Local Government Board in 1874, in which he so clearly and concisely sums up the existing knowledge on this subject, that, although the following extract is rather long, no apology seems necessary for inserting it.

"7. An important suggestion of modern science with regard to the nature of the operations by which filth, attacking the human body, is able to disorder or destroy it, is: that the chief morbific agencies in filth are other than those chemically identified stinking gaseous products of organic decomposition which force themselves on popular attention. Exposure to the sufficiently concentrated fumes of organic decomposition (as, for instance, in an unventilated old cesspool or long-blocked sewer) may, no doubt, prove immediately fatal by reason of some large quantity of sulphide of ammonium, or other like poisonous and fœtid gas, which the sufferer suddenly inhales; and far smaller doses of these fœtid gases, as breathed with extreme dilution in ordinary stinking atmospheres, both give immediate headache and general discomfort to sensitive persons temporarily exposed to them, and also appear to keep in a somewhat vaguely depressed state of health many who habitually breathe them; but here, so far as we yet know, is the end of the potency of those stinking gases. While, however, thus far there is only the familiar case of the so-called *common chemical poison*, which hurts by instant action, and in direct proportion to its palpable and ponderable dose, the other and far wider possibilities of mischief which we recognize in filth are such as apparently must be attributed to *morbific ferments* or *contagia*; matters which not only are not gaseous, but, on the contrary, so far as we know them, seem to have their essence, or an inseparable part of it, in certain

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[1] Report on the Census of Boston, by Josiah Curtis, M.D., Boston, 1876, 8vo, p. 83.

solid elements which the microscope discovers in them; in living organisms, namely, which in their largest sizes are but very minute microscopical objects, and at their least sizes are probably unseen even with the microscope; organisms which, in virtue of their vitality, are indefinitely self-multiplying within their respective spheres of operation, and which, therefore, as in contrast with common poisons, can develop indefinitely large ulterior effects from first doses which are indefinitely small. Of ferments thus characterized, the apparently essential factors of specific chemical processes, at least one sort—the ordinary septic ferment [1]—seems always to be present where putrefactive changes are in progress, as of course in all decaying animal refuse; while others, though certainly not essential to all such putridity, are in different degrees apt, and some of them little less than certain, to be frequent incidents of our ordinary refuse.

. . . .

"It must be remembered that gases on the one hand, and the particulate ferments on the other, stand in widely different relations to air and water as their respective media of diffusion. The ferments, so far as we know them, show no power of active diffusion in dry air; diffusing in it only as they are passively wafted, and then probably, if the air be freely open, not carrying their vitality far; but, as moisture is their normal medium, currents of humid air (as from sewers and drains) can doubtless lift them in their full effectiveness, and if into houses or confined exterior spaces, then with their chief chances of remaining effective; and ill-ventilated low-lying localities, if unclean as regards the removal of their refuse, may especially be expected to have these ferments present in their common atmosphere, as well as of course teeming in their soil and ground-water."

. . . .

"8. Populations under the influence of filth are in many cases suffering not only from that influence, but also from other removable causes of disease; and in any endeavor to estimate at all exactly, as for administrative judgment, the injury which is derived from filth, evidently those additional influences, should as far as practicable be made matter of separate account. In one case a filthy neighborhood may be so poor that mere privation is an appreciable cause of disease in it. In another case the population may be so badly housed, in respects which by themselves would not be classed as filth—may be so overcrowded in their dwellings, or be inhabiting such close or ill-built quarters, that this has to be counted as causing disease. In a third case, some particular collective occupation, injurious to the adults and adolescents who follow it, may be creating disease additional to that which the filth produces. In a fourth case, swarms of infants and young children, whose mothers are engaged away

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[1] For convenience I use the singular number, but have no intention of implying that ordinary putrefactive changes have only one ferment which can be considered habitual to them.

from home in some local industry, may be suffering disease from neglect and mismanagement, and so forth. And evidently, if one would see what harm filth can do in its own ways, one must discriminate it as far as possible from such concomitants as the above.

"In filthy urban districts, where the foul air, comparatively incarcerated in courts and alleys and narrow streets, can act with most force in regard to masses of population, the population always shows an increased mortality under several titles of disease. Such miscellaneous increase of mortality affects, probably, all ages, more or less, but a distinctively large proportion of it attaches to the children. Apparently the mere influence of the filth (apart from other influences) in such a district will be causing the infants and young children to die at twice, or thrice, or four times their fair standard rate of mortality; and this disproportion, which becomes even more striking when the chief epidemics of ordinary childhood (measles, and whooping-cough, and scarlatina) are left out of the comparison, seems to mark the young lives as finer tests of foul air than are the elder and perhaps acclimatized population.

"In trying to analyze the death statistics of filthy districts, we soon find that, with regard to many of the separate elements in the miscellaneous mortality, we cannot argue in exact scientific terms, partly because very large quantities are registered under names which have no definite nosological meaning—*e. g.*, "convulsions," "teething," "atrophy," "consumption;" partly, also, because some kinds which we can fairly identify by name (*e. g.*, pneumonia) are such as we do not always etiologically understand; and sometimes we may be only able to establish the broad fact that, within the area of filth, the deaths, in total amount, are greatly more numerous than they ought to be, and that the excess (or, in mixed cases, a certain share of the excess) can only be accounted for as the effect of the filth."[1]

Great as is the importance of filth as one of the causes of disease, it is necessary not to overestimate it, and to beware of the popular notion that filth is almost the only thing which requires the attention of the sanitarian. It is well known that filth does not always, nor even usually, produce disease, as clearly appears from the researches of Dr. Guy on the health of nightmen, scavengers, etc.;[2] and, on the other hand, that the filth diseases, and especially typhoid fever, sometimes occur under circumstances where the ordinary recognizable forms of filth would seem to have little to do with the matter.[3] The conclusion of Dr. Cabell, from the facts collected by him, appears perfectly legitimate, viz.: that it appears that at various times a fever, having the clinical characteristics of the typhoid-

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[1] (See Reports of the Medical Officer of the Privy Council and Local Government Board, N. S., No. 1, London, 1874. Filth Diseases and their Prevention, pp. 8-9, 10, and 11-12.)

[2] Compare also Noble on certain popular fallacies concerning the production of epidemic diseases, Manchester, 1859, 8vo.

[3] See The Etiology of Enteric Fever, by J. L. Cabell, M.D., Trans. Am. Med. Association, 1877. p. 411.

enteric fever, has prevailed in large areas of country in Virginia, generally succeeding a like prevalence of periodic fever, which in a very great degree subsides on the appearance of the typhoid affection, and he concludes that this disease cannot be prevented in these districts by exclusive attention to the removal of the products of either animal or vegetable decomposition.[1]

What is ordinarily known as cleanliness will not only have no effect upon the spreading of the true contagium diseases, such as scarlatina, but may seem to be of no avail in preventing the class of diseases referred to by Mr. Simon.

Yet the evidence that filth is a constant source of danger is so strong, and the good effects of preventing its accumulation have been, upon the whole, so evident, that it is not strange that it should seem to those sanitarians who have more zeal than knowledge, and who are not accustomed to the modes of thinking of the scientific investigator, as if discussions upon other possible causes or refinements in diagnosis were unnecessary, as if, to use the words of Mr. Chadwick, "the medical controversy as to the causes of fever, as to whether it is caused by filth and vitiated atmosphere, . . . does not appear to be one that for practical purposes need be considered, except that its effect is prejudicial in diverting attention from the practical means of prevention." This is the phraseology of the so-called practical man who thinks that "he knows enough," but the idea which it embodies is entirely erroneous. As stated by Dr. Netten Radcliffe, "the fundamental principle of sanitary practice is the discrimination of conditions under which disease prevails. As a corollary, a knowledge of these conditions is necessary to an intelligent adaptation of remedial measures. . . . The cleanliness at which hygienic measures aim, if it is to be other than a delusion, must be founded on an intelligent appreciation of that aim, and such appreciation involves a knowledge of the conditions under which the diseases to be affected by the measures exist. To relegate sanitary matters to 'common (notions of) cleanliness' and to 'common sense,' is to relegate them to general ignorance and to general slovenliness."[2]

Mr. Chadwick, however, takes a wiser view in his address at the International Congress of Hygiene at Paris, in which he remarks that "routine statistical returns of the fact of death, and even of the classes of diseases of which the patient died, without reference to the preventable causes, are positively pernicious, as tending to extend a fatalist impression that such deaths and diseases are the results of inscrutable causes, that the best that can be done has been done. . . . It is customary in these reports to give solely the mean of the death-rate of an entire city, which comprises the mean of populations in extremely opposite civic con-

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[1] Consult also W. H. Bramblett: The Etiology of Typhoid Fever, Virginia Med. Monthly, Oct., 1878, p. 517.

[2] J. N. Radcliffe: The Fundamental Principles of Sanitary Method, Practitioner, London, Sept., 1878, p. 225.

ditions. A mean between the conditions of Dives and Lazarus tends to make it apparent that after all Lazarus has not so much to complain of."

It is not only impossible to practically carry out sanitary measures to the best advantage without a comprehension of the scientific principles on which they are based, but the duty of a sanitarian is by no means completed when he has mastered the existing formulas of hygiene and their practical application.

It is his business to increase knowledge, and in no field of scientific inquiry at the present time are there greater opportunities for so doing.

To this end it is desirable that he should be familiar with the disputed points—the border-lands of sanitary science—in order that no opportunity may be lost of rescuing some portion, be it ever so small, from the marshes of theory and empiricism which surround them. Every epidemic, great or small, even if there be but three cases showing a community of origin, is an experiment performed for him, an experiment which he neither can nor dare perform for himself, and which will never be repeated in all its details. Hence, the immense importance to the sanitarian as well as to the medical man of knowing how to observe, which in most cases includes the knowing what to observe and *what to omit.*

The method of investigation of epidemics formulated by the French Academy of Medicine in 1828 laid great stress on the topography and meteorology of affected places, for obtaining which detailed instructions are given, somewhat less stress on the history and pathological anatomy of the disease itself, and dismisses other points with a few words.

Many investigations have been made upon this plan, but without obtaining very decided results, and it has gradually become apparent that continuous morbility and mortality statistics not only of localities affected, but of those not affected, are necessary to make the meteorological and topographical data of any special value.

It is much easier to obtain really useful statistics in questions of etiology than in questions of therapeutics, although their results are more frequently underrated in the former and overrated in the latter,[1] but it must be remembered that statistics but rarely originate knowledge—they are simply the balance in which the observations are weighed—and as the great majority of observers see only that which they are looking for, the most useful statistics are those collected to answer certain definite questions.

Difficult as it is to obtain statistics, it is equally difficult to use them rightly when obtained, "Testimonia ponderanda sunt antequam numeranda," but even when this has been done much remains.

When the figures have been obtained, arranged in tables, and summed up, most people suppose the work is done, whereas the skilled statistician knows that it is only fairly begun. He has still to answer three questions, viz.: 1st, what is the amount of probable error in the

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[1] See Brit. and For. M.-C. Rev., 1854, XII., 6.

results ; 2d, what is proven or rendered probable by them ; and 3d, what is the degree of this probability.

It will surprise those who have given little attention to the mathematics of probabilities to see how the results of medical and sanitary statistics shrink and dwindle on the application of Poisson's formula.[1]

Even when we find from the figures that a certain result is probable, we want this probability expressed in a known standard.

It should be remembered that "negative evidence means evidence to the contrary, not the absence of all evidence; probable extends from even chances to positive affirmation, improbable from even chances to positive denial." For instance, it is probable that typhoid fever is due to a specific microzyme. It is probable that in some cases typhoid fever has appeared in a community without the importation of this specific microzyme. It is improbable that this specific microzyme should be spontaneously generated. Try to express in figures these probabilities and improbabilities, and to deduce from the results in mathematical terms the relative probabilities of, 1st, errors in observation ; 2d, spontaneous generation of the microzyme ; 3d, its being brought from a distance by aërial currents. The statistics which previously appeared so plain and satisfactory will probably have a very different aspect before the answer is obtained.

A question of great interest in etiology, and which can only be settled by statistics, relates to the concurrence of diseases and the sequence in which they follow each other. Allusion has already been made to the researches of Dr. Buchanan on this subject (page 14), from which it appears that such concurrence is found in certain cases.

Whether these coincidences are merely accidental, or whether they show a relation of cause and effect, or a common cause, such as the pandemic waves of Dr. Lawson, is as yet uncertain, and the determining this point may prove very valuable as to prognosis and prevention.

Of late years the greatest advances in our knowledge of the causes of disease have been made, not by statistics, but by experiment and by investigations in comparative pathology. The utility of this method is limited by the fact that specific diseases seem usually specific to certain animals, and that many of the diseases of man cannot be communicated to the lower animals ; but as yet our knowledge on this subject is extremely imperfect, and the relations of the diseases of animals to those of man, of epizoötics to epidemics, etc., belongs especially to sanitary science.

Evidently, if we are to investigate to good purpose the nature of a poison, we must have some satisfactory test of the presence of the poison. The reason why we have been able to make some advance in our knowledge of splenic fever, and little or none for many years in our knowledge of yellow fever, is because we can produce the first-named disease in ani-

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[1] Probable error $= \frac{p}{q} + \frac{\sqrt{8p(q-p)}}{q^3}$ where $q =$ total number of events
$p =$ number of events in one direction.

mals, thus having at our command a physiological test whereby we may know whether we actually have the poison before us, while little has been effected, or even attempted, to obtain such a test for the yellow fever poison.

Attempts have been made, it is true, to inoculate this poison on man, and it has been observed that calves and unacclimated northern cattle will become affected during an epidemic with peculiar symptoms, such as yellowness of the conjunctiva, hæmaturia, etc., but these are simply indications for the work which is yet to be done. Dr. B. W. Richardson asserts that by the giving of large doses of alkalies to animals, he has developed symptoms similar to those of typhus, and concludes "that by experiment it might be ascertained:

"1. In what excreta the poisons of certain epidemic diseases are located.

"2. By what surfaces of the body such poisons may be absorbed, so as to produce their specific effects.

"3. Whether the virus of a disease, in reproducing its disease in a healthy body, acts in the development of the phenomena by which the disease is typified, primarily or secondarily, *i. e.*, by its own reproduction and presence, or by the evolution of another and different principle or product.

"4. Whether climate, season, and other external influences, modify the course of epidemics, by producing modifications of the epidemic poisons, or modifications in the system of persons exposed to the poisons."[1]

It is quite possible that, as civilization progresses, new sources of disease may be developed; as, for example, yellow fever is believed by many historians to have been developed by the colonization of the West Indies from Europe; that "the opening of new territories will have its dangers," and that "indigenous germs of disease may exist in unexplored Africa and in other secluded parts of the globe, which are in time to be conveyed to the marts of commerce, and thence to be still more widely diffused;"[2] but if this shall occur, it is quite certain that the success in discriminating these diseases and in fixing on their causes will be in precise proportion to the knowledge of diseases now existing which may be possessed by those who first meet with the new disease; for, as it is the first cases in an epidemic which are the most important, and which are most frequently mistaken, still more would this be the case with an entirely new disease.

In so far as the origin and spread of epidemic diseases depend upon atmospheric changes, we can do little or nothing to modify their course, and hence the study of meteorological conditions in connection with the etiology of disease is, to the sanitarian, at present, of no great practical

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[1] Brit. Med. Jour., London, 1855, pp. 213–14.

[2] G. M. Smith: Epidemics of the Century, Trans. N. Y. Acad. of Med., 1876, p. 363.

value, except to give him the power of prediction to a limited extent. During the last hundred years a vast amount of labor has been expended by medical men in obtaining and recording meteorological data, in the hope of establishing some connection between these and the variations in disease; but, as a rule, it has been labor wasted so far as this object is concerned, for the simple reason that the variations in disease have not also been recorded, but merely estimated and guessed at.

No substantial addition in this respect has been made to the knowledge possessed by Hippocrates, as set forth in his book on airs, waters, and places, namely, that cold and damp weather produces diseases of the respiratory organs; hot weather, disorders of the digestive organs; spring and autumn, malarial troubles, etc.[1]

Our hope of substantial scientific progress in knowledge of the causes of disease rests mainly on two methods as yet little used, namely, on the registration of disease and on comparative experimental pathology.

III.—Jurisprudence of Hygiene.

Whatever may be the nature or the precise causes of an epidemic, endemic, or prevalent disease, it is evident that the great majority of individuals in a community can have but little power as individuals to avoid, prevent, or destroy these causes. They do not, in fact, know what these causes are, or how to recognize them. Their hereditary organization, education, habits, and occupation, the climate in which they live, and even the quality of the air, food, and water which they use, are all established for them, rather than by them, so that if anything approximating a perfect system of hygiene depended on individual effort, we might conclude that the belief in the possibility of such a system is "one of those dreams which breathe a blind hope into us, a hope born only of our longings and destined to die of our experience," and that "in the scheme of Providence it may not be meant that man shall be healthy."[2]

But when from the individual we turn to the community, and consider it not as a mere collection of isolated and independent persons, but as a distinct organism possessing its own individuality, and having powers and responsibilities of its own, the case is very different.

It is true that the State, like the individual, is limited by its descent and surroundings, and that the city as well as the citizen must follow the thread of the Fates; but "one blade of the fatal shears is usually forged by the city itself," and thus, to a great extent, can it control the destiny of its children as regards health and longevity.

This control is to be obtained by knowledge—special and highly de-

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[1] For views in opposition to this, see Sixth Report State Board of Health of Michigan for 1878, p. 300. In this and other reports of Dr. Baker the best possible has been done with the materials at his command to show the connection between meteorology and morbility, and the scientific interest and value of such work is not denied.

[2] Parkes E. A.: Manual of Hygiene, 5th Ed., 1878. Introduction, p. xxi.

veloped knowledge on the part of a few—and a general knowledge of the utility of following the advice of these few on the part of the many, which last is much more frequently present than the equally essential knowledge as to who are the men who are actually capable of rightly directing the people, instead of those who merely claim such ability.

In the days when such science as existed was the prerogative of a comparatively small class, this last problem was not so difficult, for if the Egyptian priest, the Chaldean magus, or the Indian brahmin did not possess the desired knowledge, it was useless to seek elsewhere for it; and the motive of the multitude for following their orders was strong and direct, since it was supposed that disobedience would result not only in punishment in this world, but also in the next.

Whether Moses summed up the esoteric knowledge of the Egyptian priests in his hygienic precepts to the children of Israel, or obtained them by special Divine inspiration, does not matter in this connection. These precepts became a part of the Jewish religion, and their results are perhaps yet apparent in the vital statistics of the race, while the declaration of Mohammed that "the practice of religion is founded on cleanliness, which is one-half the faith and the key of prayer," had a much greater practical sanitary value than any similar utterance could have to-day.

In this generation it is necessary to establish public hygiene upon another foundation to ensure the general acceptance of its commands, namely, on utilitarianism—*i. e.*, to show that it contributes to the pleasure or profit of the community enough to warrant the sacrifice of a small part of the pleasure or profit of the individual. The remark of Dr. Parkes, that this will dictate a course in harmony with one of the foremost rules of religion, viz., that we should do for our neighbors as for ourselves, is certainly correct; but the sanitary law-makers of the nineteenth century usually seek first what is expedient and pecuniarily profitable, and devote their spare time afterward to proving that it is also in harmony with the creed.

The broad general principle upon which all modern sanitary legislation rests is that every member of the community is entitled to protection in regard to his health, just as he is in regard to his liberty and property, and that on the other hand his liberty and his control of his property are only guaranteed to him on the condition that they shall be so exercised as not to interfere with the similar rights of others, nor be injurious to the health of the community at large. Health in this connection is not merely analogous to capital or property, but it *is* capital, the value of which may be to a certain extent expressed in coin, and its protection may be based upon the legal principles which relate to the protection of rights of property, although it rests also on other principles of State polity which concern the jural and moral relations of human life.

Those who believe that certain rights of man do not depend upon expediency or utility as measured by human standards, but upon a certain moral order arranged by the creator, and expressed either in a special revelation or in certain universal human instincts, do not usually include sanitary rights among such. Thus, Professor Woolsey says: "Sanitary regulations tend to preserve health and life, but only in an indirect way, and so they are not a necessary part of State action. It is not evident that a swamp ought to be drained by the State, or under its direction by the district, for the purpose of diminishing malaria, because the right to life requires it, any more than physicians and medicine ought to be supplied by the State because the right to life requires it. The right to life is of another sort; and it does not say to the State 'Thou shalt keep this or that man from sickness such as the soil or climate may bring upon him,' any more than the rights of property say 'Thou shalt keep this or that man from poverty occasioned by his neighbor's superior skill.'"[1]

The author's illustrations are not good, since they involve the fallacy that there is but one kind or degree of expediency, whereas the difference in this respect in the instances given by him is very great; but the point made that sanitary matters are things in which the State *may*, but not *must*, interfere is correct, nor does he by any means deny the expediency or propriety of such interference.

But, putting aside altogether considerations of moral right or divine commands, the sanitary rights of the people depend to a great extent upon that part of law which Hobbes describes as "that law which men are bound to observe because they are members, not of this or that community, but of a community," and these rights, and the obligations connected with them, can be defined with reasonable clearness and precision, whence it follows that they are proper subjects for legislation whenever such definition becomes expedient.

On the other hand, justice compels no man to perform any act for which a moving consideration or advantage to him has not existed, or will not exist in the future ; or, as Ordronaux states it: "The foundation of mutuality of obligation subsisting between men in civil society rests upon the doctrine that each member has rights of which he cannot with propriety be divested ; and that in the exercise of these rights, and in the ordinary transactions of every-day life, he is entitled to a *quid pro quo* for every advantage, privilege, or favor granted to another."

As I have elsewhere remarked: "When the State says to the individual citizen, 'You shall not, as heretofore, allow the waste from your factory to contaminate the stream upon which it is placed ; you shall not slaughter cattle in the buildings which you have erected for that purpose ; you shall not build a house on a certain lot of yours, unless you make the walls of a certain thickness and arrange the timbers in a certain way :' when she says to the physician, 'You shall keep certain records and make certain reports, in order that we may know the rates and causes of disease ;' or to the householder, 'You shall ventilate your sewer-connections in a certain way, and you must put in a particular form of trap ;'—it may seem at first sight that these persons should be compen-

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[1] T. D. Woolsey : Political Science, N. Y., 1878, Vol. I., p. 220.

sated by the community for this abridgment of their liberty, or for the service which they are compelled to perform."[1]

A little consideration, however, will show that these and similar commands derive their authority from different sources.

The first of these sources is what is called the "right of eminent domain," *i. e.*, the right of a government to take private property for public use, whenever it is necessary for the public good, or to demand the services of individual citizens for the same reason ; but in this case it is always the duty of the State to furnish a reasonable compensation for the property or labor thus appropriated. The compelling physicians to furnish statistics falls under this head.

The second source of authority is what is called the "police power," and with regard to this we cannot do better than quote from the opinion of Chief Justice Shaw, in the case of the State of Massachusetts *v.* Alger.

Speaking of the police power, he says: "It is the power vested in the Legislature by the Constitution to make, ordain, and establish all manner of wholesome and reasonable laws, statutes, and ordinances, either with penalties or without, not repugnant to the Constitution, as they shall judge to be for the good and welfare of the commonwealth, and of the subjects to the same.

"It is much easier to perceive and realize the existence and sources of this power than to mark its boundaries or prescribe limits to its exercise. There are many cases in which such a power is exercised by all well-ordered governments, and where its fitness is so obvious that all well-regulated minds will regard it as reasonable. Such are the laws to prohibit the use of warehouses for the storage of gunpowder near habitations or highways ; to restrain the height to which wooden buildings may be erected in populous neighborhoods, and require them to be covered with slate or other incombustible material : to prohibit buildings from being used for hospitals for contagious diseases, or for the carrying on of noxious or offensive trades ; to prohibit the raising of a dam, and causing stagnant water to spread over meadows near inhabited villages, thereby raising noxious exhalations injurious to health and dangerous to life.

"Nor does the prohibition of such noxious use of property—a prohibition imposed because such use would be injurious to the public—although it may diminish the profits of the owner, make it an appropriation to a public use, so as to entitle the owner to compensation. If the owner of a vacant lot in the midst of a city could erect thereon a great wooden building, and cover it with shingles, he might obtain a larger profit of his land than if obliged to build of stone or brick, with a slated roof. If the owner of a warehouse in a cluster of other buildings could store quantities of gunpowder in it for himself and others, he might be saved the

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[1] Public Health Reports and Papers : Am. Pub. Health Assn., Vol. III., N. Y., 1877, p. 49. Consult also, Die öffentliche Gesundheitspflege und das Recht des Einzehren, von Dr. Gottisheim, Deutsche Vrtljhrschr. f. öffentl. Gsndhtspflege, 1877, IX., p. 467.

great expense of transportation. If a landlord could let his building for a small-pox hospital or a slaughter-house, he might obtain an increased rent. But he is restrained: not because the public have occasion to make the like use, or to make any use of the property, or to take any benefit or profit to themselves from it; but because it would be a noxious use, contrary to the maxim *sic utere tuo, ut alienum non lædas.* It is not an appropriation of the property to a public use, but the restraint of an injurious private use by the owner, and is therefore not within the principle of property taken under the right of eminent domain."[1]

It should be observed that the police powers of the State are for the most part exercised to secure non-interference—that is, for negative rather than positive results. The majority of the commands issued under it are in the formula "Thou shalt not." Legally, a man is not to be his brother's keeper; he is simply compelled to refrain from injuring his neighbor. By some writers, as William von Humboldt and John Stuart Mill, it is denied that the State should directly attempt to improve the physical welfare of its citizens, on the ground that such interference will probably do more harm than good. But all admit that the State should extend special protection to those who are incapable of judging of their own best interests, or of taking care of themselves, such as the insane, persons of feeble intellect, or children; and we have seen that in sanitary matters the public at large are thus incompetent.

The only practical test as to what a State should, or should not, attempt in this matter is expediency; whence it follows that, since this test must vary according to place, race, and degree of civilization, no general and absolute rules can be laid down. However great the importance which may be attached to decentralization and the distribution of administrative powers, and to the inexpediency of concentrating in bureaux all the skill and experience in organization existing in the community, there can be no objection to the State's collecting information, giving advice, and stimulating and aiding the work of local organizations. The power which may be exercised in this way is none the less real, because it does not appear in direct commands.

In a large part of the United States, public hygiene is a matter of common law only, and may be summed up in the regulations relating to nuisances. As it is highly important that the sanitary official should understand the relations of the law of nuisance, a few words will be given to that subject.

In this country we are said to have constitutional law, statute law, and customary or common law. This last is made up of a body of customs, traditions, and usages, derived in the main from England prior to the American revolution, but since added to in the several States.

There is no common law of the Union, nor have the federal courts jurisdiction of common law offences, and what is common law in one State

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[1] Reports of Cases Argued and Determined in the Supreme Judicial Court of Mass., by Luther S. Cushing, Vol. VII., Boston, 1853, pp. 84–86.

may not be and frequently is not so considered in another.[1] These customs are transformed into legal rules by judges, whose decisions are the main sources of information as to what is and what is not common law; and with regard to what is and what is not a nuisance, these decisions are summed up as follows:

The use of one's own property in such a way as to injure the rights of another and to inflict damage is the essence of nuisance. There must either be a definite tangible injury to person or property, or the enjoyment of property must be rendered essentially uncomfortable, and there must also be an injury to the rights of another. If a man digs a cellar on his ground, no matter how deep, and the foundations of his neighbor's house are thereby endangered, he does not commit a nuisance, because, although he may inflict great damage, he injures no rights. If he collects on his own premises, for his own pleasure or profit, any material such as water, or filth of any kind, he is bound to let none of it escape in such a way as to do damage.

It has been decided that this applies also to gases, vapors, and odors, and the decision of Mansfield in the case of Rex *v.* White is often quoted approvingly by jurists, viz.: "It is not necessary that the smell be unwholesome; it is enough if it renders the enjoyment of life uncomfortable" (1 Burr, 337).

Under such conditions as these it might seem as if written statute laws for the protection of the public health were not essential;—as if the views held by some (though not many) lawyers, that the powers of the common law are ample to deal with such matters, were correct. But, in the first place, there is no agreement as to the amount of discomfort necessary to constitute a nuisance, and, as Wood remarks, the importance and utility of a business have great weight in deciding the question, especially where manufacturing interests are strong, as in Pennsylvania. Theoretically, when a judge makes a legal rule it is considered as established by the sovereign power, the authority to make such rules having been given either expressly, or by implication and acquiescence, since power is given to enforce them; but practically the rule is only good for the particular case, and in that case must always be more or less of the nature of an *ex post facto* law. Since judges differ, there is much difficulty in ascertaining whether a judicial rule will be considered valid by other courts. "We never can be absolutely certain (so far as I know) that any judiciary rule is good or valid law, and will certainly be followed by future judges in cases resembling the case by which it has been introduced;"[2] and certainly in sanitary matters the common law is a very uncertain and unsatisfactory reliance.

It should be remembered, however, that it never can be done away with, and must be continually appealed to to supplement the statute law, which takes the place of only a certain portion of it; hence, the precise

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[1] Sedgwick on Statutory and Constitutional Law, N. Y., 1857, p. 17.

[2] Lectures on Jurisprudence, by John Austin, Lond., 1863, Vol. II., p. 366.

scope and wording of the statute becomes a matter of very great importance, which can only be fully appreciated by those acquainted with the common law.

So far as it relates to the public health, the principles of the common law may be summed up in the maxim, *sic utere tuo ut alienum non lædas;* but the remedy which it provides usually comes too late, since the injury has been inflicted, and pecuniary damages cannot compensate for ruined health and lost lives.

It should be remembered, however, that, unless a statute takes away the power of obtaining a remedy at common law, the party injured or aggrieved may select either mode of obtaining redress.

If a board of health assigns a place in which an offensive or dangerous business may be carried on, the person carrying on that business at that place is liable to no process therefor other than those prescribed by statute; but, if the health authorities take no action, the common law remedies, either public or private, will lie.[1] A nuisance may be public, private, or both; but, in any case, from the legal point of view, they arise from the violation of the common law, and not from the violation of rights created by statute.[2]

A public nuisance must be to the common annoyance of the public, *i. e.*, that it cannot be said that its consequences are confined to a few persons,[3] and it includes anything that is indecent or offensive to morals, such as the indecent exposure of the person in a public place.

It is a public nuisance for a person afflicted with an infectious or contagious disease to expose himself in a public place; but a person sick in his own house or in a room in a hotel is not a nuisance.[4]

Private nuisances are such as damage or discomfort but a few persons: for instance, a shop, the noise from which annoys but three or four tenements.[5] While the distinction may seem nominal rather than real, whenever the annoyance affects more than one person, yet there is a difference of procedure in seeking a legal remedy for a public as distinguished from a private nuisance. The public wrong is to be remedied by indictment, and not by a suit for damages, since the individual, in order to recover damages for injury inflicted by a public nuisance, must be able to make out a clear case of special damages to himself apart from the rest of the public, and of a different character, so that they cannot fairly be said to be a part of the common injury resulting therefrom. It is not enough that he has sustained more damage than another; it must be of a different character, special, and apart from that which the public in general sustain.[6]

Yet the nuisance may be, and often is, mixed, that is, both public and private, in which case the rule as defined by the Court of Appeals of New

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[1] Commonwealth *v.* Rumford Chemical Works, 16 Gray, 1860.

[2] Wood on the Law of Nuisances, p. 19.

[3] Rex *v.* White, 1 Burr, 333.

[4] Wood, p. 72.

[5] Rex. *v.* Lloyd, 4 Esp., 200.

[6] Wood, p. 656.

York is, "that one erecting or maintaining a common nuisance is not liable to an action at the suit of one who has sustained no damage therefrom, except such as is common to the entire community; yet he is liable to one who has sustained damage peculiar to himself. No matter how numerous the persons may be who have sustained this peculiar damage, each is entitled to compensation for his injury. When the injury is common to the public, and special to none, redress must be sought by a criminal prosecution in behalf of all."[1]

With regard to the subject of nuisances and the rulings of the common law with regard to them, it is highly desirable that in sanitary legislation the definitions of nuisances and the descriptions of modes of procedure against them should be as clear and precise as possible, whether these definitions are given in the statute creating the sanitary authority, or by the sanitary authority itself in virtue of power given to it to do so, for failure in this respect can only result in an application of the common law rulings to the matter, which will be found to be a special and peculiar nuisance to the public health in itself.

While it is clear that the duty and right of the State to make and enforce sanitary regulations depends mainly on the police power, yet the right of eminent domain may also be employed in emergencies or to compel the services of professional experts, and the distinction between these powers should not be lost sight of.

Admitting that under the police power the State should see that each individual has the power to obtain pure air, water, and food, and that no one shall wilfully or for his own advantage damage another man's supply of these essentials to health, it has still been a question how far the State under this power can interfere with ancient privileges established by custom. In the United States it has been decided that it can so interfere, upon the principle enunciated by Chief Justice Taney in the well-known decision in the case of the Charles River Bridge *v.* the Warren Bridge, viz., that States must be permitted to avail themselves of the light of modern science and of the improvements brought about by it—that, for instance, a turnpike cannot claim damages because a railroad puts its profits in jeopardy; but there is still some uncertainty as to what might be the decision in a particular case. In Massachusetts it has been decided that carrying on an offensive trade for twenty years, in a place remote from buildings and public roads, does not entitle the owner to continue it in the same place after houses have been built and roads laid out in the neighborhood, to the occupants of and travellers upon which it is a nuisance.[2]

Another question may be conveniently considered here, viz., the right of the State to interfere with the liberty of the individual for the purpose of securing health to the next generation. Why should we not by united effort, and as a body politic, endeavor to prevent the suffering, disease,

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[1] Francis *v.* Schoelkoppf, 53 N. Y., 162, and Wood, p. 677.

[2] Commonwealth *v.* Upton, 6 Gray, 473.

and vice, with which hereditary influences from the insane, the syphilitic, or the drunkard, will afflict our children's children? "To what end do we apply all the resources of modern science and art to preserve the lives of the thousands of men and women in our public asylums, hospitals and prisons, of many of whom it may properly be said that it were better they were dead than alive? We employ our best physicians and engineers to make sure that the air, water, and food of these persons shall contain nothing detrimental, and, after keeping them awhile and getting them into the best possible condition, we send them out into the community, living and moving sewers, to propagate and produce mental and physical deformity and disease without limit."[1]

The reply to this is, that the good effected by keeping criminals in good sanitary condition exceeds upon the whole the evil produced, and that the interference of the State to prevent reproduction of hereditary diseases would, in the present conditions of society, certainly cause more evil than good. As stated by Dr. Wilks,[2] "it is no doubt fearful to think of a man or woman marrying with a strong taint of insanity, and bringing into the world a family of lunatics; but it does not follow that an infusion of the insane blood may not be desirable. I think that it might easily be shown that such infusion has given genius to a whole family—it has leavened the whole mass."

The question of the prevention of hereditary diseases by State interference must be settled for those who adopt utilitarian principles, by the maxim of Sir James Fitzjames Stephen: "If the object aimed at is good, if the compulsion employed is such as to attain it, and if the good obtained overbalances the inconvenience of the compulsion itself, then the compulsion is good." Those who do not accept this principle must decide in accordance with the fact that the prevention of propagation of hereditary disease means also the prevention of life, and that between this, the prevention of conception at the will of the parents, and induced abortion, there can be no sharp dividing lines. The question is, at present, of practical interest to the legislator, mainly in regard to the management of the criminal classes and of paupers, and although closely connected with public hygiene, is, nevertheless, so distinct that it cannot be considered here.

We may now proceed to consider some of the means by which the State may, or ought to, endeavor to prevent or destroy those causes of disease which affect communities, rather than isolated individuals, and which are for the most part beyond the reach of individual effort.

To effect this, skilled labor is necessary, and also some central authority to secure uniform and harmonious action, and to both properly protect and restrict the liberty of individuals.

The fact that a community possesses political liberty by no means implies the possession of proper regulations for the care of the public health,

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[1] Public Health Reports and Papers: Am. Pub. Health Ass'n, Vol. III., N. Y., 1877, p. 50.

[2] Journal of Mental Science, Lond., Jan., 1875, p. 514.

or that such regulations would be enforced if made, the tendency appearing to be rather in the opposite direction; and the difference between communities in this respect is so great that no uniform system as to details is practicable. "A perfectly uniform system of legislation supposes equality of intelligence or injustice in the law."

In a newly-settled country, over which the population is thinly scattered, the necessity for protection of the public health is unfelt; but as wealth and population increase, the gathering of the people in masses in cities and villages both gives rise to special dangers to health and life, and makes the ordinary dangers more conspicuous. The danger cannot be estimated from the relative density of population over large areas; for instance, the number of inhabitants per square kilometre is estimated as follows: France, 68.3; Great Britain, 101; Belgium, 181; Austria, 67.9; German Empire, 75.9; China, 100.6; Japan, 82.1; United States, 5;[1] but it would be a grave error to conclude that the necessity for sanitary measures is correspondingly small in the United States, seeing that at the last census over one-fifth of the entire population was contained in fifty cities, and that since that time the increase has been markedly greater in municipalities than in rural districts. The causes of this aggregation are manifold, are still acting, and will probably continue to act for some time to come, and the results are of great importance to our sanitarians. In the cities are found the extremes of poverty, ignorance, and vice; the dangers of contagion and the infective diseases are there at their maximum; there will always be certain localities in which the children cannot be healthy, intelligent, and virtuous, and those who survive in spite of the filth which they eat, drink, breathe, and live in, form the dangerous classes, an ever-present menace to society; while on the other hand, there also are wealth and power, and the greatest possibilities of effective supervision and control.

As physicians have their attention more frequently and forcibly called to the evil results of a bad sanitary condition of the people, they are usually the first to urge legislation on the subject. But, as Mr. Eaton remarks: "The moment we attempt to exercise political power for sanitary purposes, that is, to use the government for compelling citizens to observe the general conditions of public health, and to pay the penalty of the infringement and the cost of redress, we must not seek our official force wholly from any one profession."

No single profession has either the knowledge or the power to accomplish such work, and although it may be hoped that, in the good time coming, the health official will combine in one person the special knowledge of the physician, the lawyer, the engineer, and the chemist, yet, for the present, members of each of these professions must unite to secure good work.

If it be agreed that "a requirement of good sanitary administration is universality, through constant supervision by public health officers in

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[1] Proust: Traité d'hygiène, Paris, 1877, 8vo, p. 33.

every part of the country,"[1] one of the first things to decide with regard to the proposed network of sanitary officials is the size of the meshes, or, in other words, what should be the unit of area for administration. Upon this point the best authorities in this country are generally agreed that the most practical units are the city and the county.

That each city should have its own sanitary authority is clear, since it has its own special causes of disease, and its limits are usually well defined, geographically as well as politically.

The county lines are usually not natural boundaries, and have no relation to the causes of disease ; but at first, at all events, it will be difficult to provide sanitary authorities having no relations to existing legal or political organizations, and hence these last must be carefully considered.

Three other points should receive attention in regard to the unit of area. The *first* is, that the areas should be identical with those for the registration of vital statistics. If either overlaps the other, loss of utility and power will certainly result. The *second* is, that for purposes of supervision, there are great advantages in having the areas as nearly as possible conterminous with drainage areas—in other words, the boundaries should not be streams, but ridges, and this remark applies to all units of area for vital statistics. The *third* is, that as far as possible the area should be large enough to occupy all the time of the inspecting and executive sanitary forces. The larger the area the greater the ability to pay for the services of suitable men ; and trained intellect, combined with high character, is an expensive article to provide, although it is in this case certainly true economy to do so. Moreover, the larger part of the work can only be properly done by men having a medical education, and these men should not be practitioners, for reasons well summed up by the English Board of Health, as follows:

. . . . "But, where possible, it will be well to debar him from the private practice of his profession :—first, because the claims of such practice would be constantly adverse to those of his public appointment, the duties of which (especially at times of epidemic disease, when his official activity would be most needed) private practice could scarcely fail to interrupt and embarrass; secondly, because the personal relations of private practice might render it difficult for him to fulfil with impartiality his frequent functions of complainant; and, thirdly, because, with a view to the cordial good-will and co-operation of his medical brethren, it is of paramount importance that the officer of health should not be their rival in practice, and that his opportunities of admonitory intercourse with sick families should not even be liable to abuse for the purposes of professional competition."[2]

Attempts to combine the functions of a health officer with those of a physician for the poor have been often made, but the result is unsatisfactory. It is undesirable that the practice of a physician should be exclu-

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[1] Second Report of the Sanitary Commission, Vol. II., Lond., 1871, p. 351.

[2] General Board of Health: Instructional Minute relative to the Duties and Qualifications of Officers of Health, in Districts under the Public Health Act, 1848, p. 5.

sively among the poor, because it deprives both the poor and the rich of the benefit of wide and varied experience, a loss which is especially apparent during the prevalence of epidemics, and the area which can properly be assigned to a medical officer for the poor is much smaller than that which can be given to a properly qualified health officer. Such a health officer can properly superintend an urban population of from 125,000 to 200,000.[1]

There is a marked difference between city and country as to the character of information which may be obtained as to causes of disease. In the city we obtain the best statistics, but the country affords special facilities for obtaining the history of individual cases as to their etiology.

The areas being defined, the next question to be considered is the organization, powers, and duties of the Sanitary Board. Should the specially skilled hygienist be employed merely to give advice, as in France, or be made an integral part of the executive organization?

The public health institutions of France have been much praised, and, on paper, the plan of a council of experts for each district looks well; but, practically, the councils of health of the smaller areas really do nothing, and the advice of the others is often not attended to.[2]

It is now a well-recognized fact that the sanitary organization of a city, to secure efficiency, should have certain legislative, judicial, and administrative powers, and its responsibility being great, it should be neither too much concentrated nor too much diluted. The execution of a health law cannot be a matter of mere routine; it requires special knowledge and experience. The health officials are not simply directed to do a specific thing; they are to discover causes as yet unknown, to devise remedies, and to see that these remedies are applied. The organization for this purpose usually preferred is a board of health, the most convenient number for which is five, and it should be composed of men of different professions, including medicine, law, and engineering, although the principal executive officer should combine in himself much of the knowledge of the three.

How are the best men for this purpose to be selected? Neither election by the people nor appointment by municipal authorities has been found to give uniformly good results. What the results may be are shown in the case of New York City. "Men elected by party caucuses were treated as competent to administer the science of health and to solve the problems of sanitary precaution. Health wardens and other officers were allowed to be selected and salaried without limit by the city aldermen and councilmen. It is no wonder that the exercise of sanitary authority soon became a greater peril than miasma and contagion; that political doctors became the agents of partisan and mercenary city officials; that mayors of New York, by no means scrupulous or timid, did not dare, for a whole term, to even call a meeting of the New York Board of Health; that of the forty-eight health wardens and assistants, more than

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[1] See Brit. Med. Jour., Nov. 11, 1871, p. 569.

[2] See Armaingand: De nos institutions d'hygiène publique, Paris, 1873, 8°; and Recueil des travaux du comité consultatif d'hygiène publique de France, Tome VII., 1858, p. 58 et seq.

one-half were keepers of corner groggeries, and the other half were partisan repeaters and bullies; that nearly the whole sanitary force of the city was, for utility, worse than a sham, and was, in reality, a scandal and a peril to a civilized community."[1]

In no other city have the results been so bad as this; but the rule is that appointments are made with reference to political influence, and that professional qualifications have been a secondary consideration. To appreciate the causes of this it is necessary to refer briefly to a subject much wider than and including public hygiene in the special technical sense in which we are using that phrase, namely, State medicine, which includes also medical education and medical jurisprudence. Since a large part of the information required by the sanitarian can only be obtained from medical men, whose intelligent co-operation is absolutely essential to his success, it is evident that the relations of the physician to the State must strongly influence the possibilities of public health organization.

When the State undertakes to obtain and secure properly educated physicians for its citizens, by fixing directly or indirectly a minimum standard of qualification, and by imposing penalties or disabilities upon those who do not come up to this standard, it can properly call upon these physicians for assistance in preserving the public health to an extent which would be not only unjust, but impossible, in a community where the ignorant pretender is on the same footing as the accomplished physician. This is not merely due to the fact that the physician, like other members of society, has the right to demand compensation for information furnished or for services rendered, but also to the fact that the ignorant practitioner cannot perform the duties required by the sanitary authorities.

Since, in the majority of the States in this country, there are no legal restrictions upon the practice of medicine, and the properly qualified practitioner receives no special recognition or encouragement from the State, the only way in which the State can justly obtain information or aid from him is by paying for such service.

It is, however, extremely difficult to arrange for making such payments in money, nor would that method be satisfactory to the physicians; and as it is very important that their assistance should be willingly furnished, it is much better that the compensation should be indirect, in the shape of certain privileges. For many reasons one of the most desirable of these privileges is that the physicians interested shall have a voice in the selection of the health official or officials with whom they are to co-operate, and shall have some permanent and recognized means of representation in the councils of the sanitary authority.

Through local medical societies it is usually not difficult to effect this, so far as the physicians are concerned; hence the responsibility of effecting it must rest almost entirely upon the appointing powers and with the health officials themselves. As yet it is difficult to find men properly qualified to perform the duties of health officers, but there is no doubt

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[1] From Sanitary Legislation in England and New York, by D. B. Eaton, 1872, p. 31.

that the demand will create the supply, and even now a suitable man can be obtained for an adequate compensation, which last at present is seldom or never offered.

The public at large in this country, as in England, "underrate the knowledge and qualities requisite for giving trustworthy advice in this direction," nor is the importance of having at hand an authoritative means of seeing that health interests are consulted in all public buildings or works by any means appreciated.

The public find no special difficulty in securing, by election or appointment, men capable of serving them as legislators or administrators, and do not see why a different mode of selection should be applied to sanitary officials. But, as pointed out by Dr. Leconte, "the men of science, who carry on unceasing war against the children of the four great bogies—self-will, ignorance, fear, and dirt—are not educated by the processes of the common school, nor are they elevated to position by the votes of their fellow-citizens; rarely, indeed, are they by the choice of the popular rule placed in position commensurate with the usefulness they are capable of exercising." Dr. Leconte advises as a remedy for this "that the officers in whom the power of appointment resides should act on the recommendation of those societies or organizations which have been formed to promote the particular branches of science or technical knowledge upon which the duties to be performed depend."

The question is complicated by the existence of certain schools of medicine which claim to practise in certain peculiar ways, and that these ways only are correct. The homœopathic school, for instance, although divided in opinions, may be said to teach that the methods of practice of the great majority of physicians of the civilized world are erroneous.

Now, while it may be admitted that under the police power each State may prescribe the qualifications which shall be possessed by practitioners of medicine within her borders, yet it is in the highest degree inexpedient that it should prescribe what form of medication shall or shall not be employed. A standard of education is a very different thing from a standard of action.

The combined action of homœopathic physicians in preventing the formation of State boards of health, or in causing the insertion of provisos for the appointment of homœopathic physicians as members of State boards of health, has been several times exerted successfully, which fact is a sufficient proof of the numbers and influence of this school.

Now, while there is a special exclusive homœopathic therapeutics, no special homœopathic hygiene has as yet been developed. Some Hahnemannian homœopaths may have very peculiar ideas as to the causation of disease, but even they do not deny the influence of filth, contagion, etc., and hence there is no special reason on their part for not uniting in the destruction of these causes.

There are, it is true, good reasons why skilled sanitarians prefer to have the least possible association with practitioners of exclusive views, with men who publicly proclaim that they know more than any of the physiologists, pathologists, or other well-recognized scientific investigators and promoters of medical knowledge; but they must deal with such men until the Millennium comes, and must do the best they can with their statistics.

To what extent centralization of governmental interference to secure the public health is desirable or expedient, is a serious and very difficult question, the answer to which, as pointed out above, cannot and should not be the same in different countries. Some would have the central government assume entire control of sanitary matters, registration, quarantine, building regulations, etc., holding, in fact, views analogous to those held by the advocates of government supervision of railroads, telegraphs, hours of labor, and wages. A curious illustration of the extent to which this idea may be carried will be found in Bentham's scheme of the duties and powers of a health minister, forming a part of his "Constitutional Code."[1] Bentham's health minister is to carry out all laws for the preservation of the public health; to appoint and control all medical officers of the army, navy, public charities, etc.; to supervise medical education, pharmacy, etc.; to have charge of the inspection of all prisons, asylums, school-houses, and other public buildings; and of vital statistics, weather registration, government medical museums, systems of water-supply, drainage, etc., etc. One clause is so curious that I transcribe it literally:

"Art. 21, VII. *Professional confederacy-checking function.*—To the health minister, under the direction of the prime minister and the legislature,— . . . it will especially belong to be upon the watch against all injury to the health of the community, by the operation of particular interests in the breasts of medical practitioners, at the expense of public interest: for example, by associations among themselves for the formation of regulations and arrangements, express or tacit, concerning divison of labor, rate of payment, terms or mode of attendance, or otherwise."

Evidently our code of ethics and medical fee bills would give such a minister abundant employment.

When public health becomes a matter of real interest to a nation, the influence which attempts to control it may exert toward centralizing government, even in other departments, is important, and should not be overlooked. The desire for local self-government seems to many a great obstacle to sanitary progress, and no doubt this is often the case; but an attempt should be made to secure both, rather than to sacrifice either for the sake of the other. In the first place, as pointed out by Mr. Jenkins, there is a difference between central supervision and central administration. The first is seeing that others do their duty; the second is doing duty by means of others. In the one case there is a certain amount of independence, in the other there is none.[2]

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[1] The Works of Jeremy Bentham, Edinburgh, 1843, Vol. IX., p. 443.

[2] The Medical and Legal Aspects of Sanitary Reform, by A. P. Stewart and E. Jenkins, London, 1867, 8vo, p. 82.

In the second place, responsibility and accountability should be connected with power wherever that may be. In the United States, at present, and probably for some time to come, only local sanitary authorities have power to deal with local causes of disease, and they should be held responsible for any evil results which follow either their failure to use that power or their improper use of it, just as the individual householder has power to abate a nuisance on his premises in his own way, but is held responsible if his method does not prove efficacious.

In order that this responsibility may exist, there must be some means of enforcing it; some authority which shall decide as to whether or not the householder or the municipality has fulfilled his or its duty to the community, and shall enforce penalties or damages in cases of neglect or failure. As the subject of causation of disease is a technical and special one, some organization of experts is necessary to obtain and furnish information with regard to it, and to decide what are the duties of individuals, corporations, or communities in this respect.

Such organizations in this country are known as boards of health. The municipal and local boards of health are chiefly occupied in fixing the duties and responsibilities of individuals. The State boards of health should deal rather with the duties and responsibilities of communities and of the local boards just referred to.

In the preparation of a law establishing such health boards some very troublesome questions arise. Many difficulties can of course be avoided by giving large discretionary powers to the sanitary authority and avoiding the specifying of these powers in detail. In this manner the law may be made brief, and in appearance very simple; and it affords a certain elasticity and means of accommodation to circumstances which might give much better results than could be obtained from a detailed, fixed, and uniform code, *provided that the sanitary authorities are properly qualified persons.* On the other hand, such a concise law must confer powers of legislation, and indirectly of taxation, to an extent which will be repugnant to many, and which might conflict seriously with other important interests, and result in great abuse. A certain amount of such legislative power must, however, be conferred upon any sanitary organization which is to have real efficiency, and the question as to whether the legislature of a State can confer such power was decided by the Supreme Court of the State of New York, as follows:

"The legislature has the power to confer the authority to enact and enforce ordinances, not only on a municipal government, but on any department of a municipal government, as, for instance, on a board of health;"[1] and this decision was reaffirmed in the case of Polinsky *v.* the State,[2] with the qualification that such ordinances must cover offences only which are not covered by a statute. The statute in general terms declares the violation of ordinances passed by the Board of Health

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[1] People *ex rel.* P. Cox, Hun, 7, p. 214.

[2] Hun, XVIII., p. 390.

to be a misdemeanor, and the same, or another statute, fixes the penalty for such misdemeanors.

Allusion has already been made to the importance of the question of cost in sanitary measures, and in framing a law to secure such it is highly desirable that it shall show as clearly as possible not only the cost of the health organization itself, but the cost of the measures which it is to be authorized to carry out.

Also it has been pointed out that the common law covers all questions not specifically settled by statute, and hence a vague and indefinite statute soon becomes of little force or value, since it will be promptly overridden and superseded by judicial decisions based on the common law, which in sanitary matters have always proved to be of little utility. On the other hand, attempts to provide specifically, as far as possible, by statute, for all emergencies, leads to great prolixity, and may even have the effect of making the law unintelligible except to a few specially skilled lawyers, leaving the average citizen very much in the dark as to how it affects him. For instance, the act creating a Metropolitan Sanitary District and Board of Health for the City of New York, passed in 1866, was, from a legal point of view, in most respects very satisfactory, but it would require a large and very carefully prepared volume of commentary to enable the average merchant or practising physician to understand its full scope.

Again, it must be remembered that the fact that legislative, executive, and judicial powers have been conferred on a board of health, does not do away with its responsibility for the results of their exercise. If it destroys property on the ground that it is a nuisance, it must be able to prove conclusively that it is a nuisance. If it authorizes the construction of a hospital for contagious diseases, in a given locality, it must be held responsible for the results, and the remedy for those to whom the hospital proves a nuisance should be, under the common law, in a court other than the board itself. Experience has shown that when cases of this kind are tried before a jury, the probability that they will be decided according to their real merits is small, and hence the decisions in the New York courts to the effect that trial by jury cannot be insisted on are regarded as very important.[1] It must be noted, however, that the reason why trial by jury was not insisted on by the court was because a jury had not been the ordinary tribunal for such cases, and hence the decision would have little weight in another State; in fact, it has been expressly decided in Massachusetts that the right of trial by jury cannot be superseded by the State board of health.

This decision was given in the case of Sawyer *v.* State Board of Health, in which it was claimed by the petitioner that if the statute of 1871 applies to his buildings and trade, and deprives him of the right of appeal to

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[1] See C. H. Reynolds *v.* J. S. Schultz et al., Robertson's Repts. Sup. Court City of N. Y., IV., 1868, p. 282, and the Metropolitan Board of Health *v.* J. Heister, Tiffany's Repts. Court of Appeals, State of N. Y., 1868, Vol. XXX., in which last the dissenting opinions by three members of the court should be carefully considered by those engaged in framing a health law.

a jury, it is unconstitutional; while it was claimed on the part of the board that the statute is simply a license law. The statute in question is as follows: "Whenever in any city or town containing more than four thousand inhabitants, any building or premises all occupied or used by any person or persons or corporation for carrying on the business of slaughtering cattle, sheep, or other animals, or for melting or rendering establishments or for other noxious or offensive trades, the State Board of Health may, if in their judgment the public health or the public comfort and convenience shall require, order any person or persons or corporations carrying on said trades or occupations, to desist and cease from carrying on said trades or occupations in such building or premises, and any person or persons or corporation continuing to occupy or use such building or premises for carrying on said trades or occupations, after being ordered to desist and cease therefrom by said board, shall forfeit a sum not exceeding two hundred dollars for every month he or they continue to occupy and use such buildings or premises for carrying on said trades or occupations after being ordered to cease and desist therefrom by said board as aforesaid, and in like proportion for a longer or shorter time: provided that on any application to said board to exercise the powers in this section conferred upon them, a time and place for hearing the parties shall be assigned by said board and due notice thereof given to the party against whom the application is made, and the order hereintofore provided shall only be issued after such notice and hearing."[1]

The boards of health of towns have the same power, but they are not obliged to give notice and hearing.

The court goes on to say: "It is undoubtedly true that the mayor and aldermen or selectmen may authorize in writing the carrying on of noxious or offensive trades at a certain place in a city or town of more than 4,000 inhabitants; and the day after the occupancy commences the State board of health may give a notice and hearing to the party thus authorized, and may issue an order forbidding the use of that place. Did the legislature intend that the town board of health might then again authorize the same business in the same place, to be again prohibited by the State board of health? We can no more suppose that the legislature intended to introduce this conflict and confusion into the law than that it intended by implication to submit the whole system of regulation by absorption into a general authority of prohibition all over the commonwealth by a board composed of only seven members, serving without compensation, and necessarily strangers to the great majority of the various municipalities, and unacquainted with their local interests. The only construction which we can give to the statute consistent with the constitution of the commonwealth, with existing laws recognized by the act itself as still in force, with the general policy of the legislation upon the subject, is to treat the power given by the statute as given subject to the same limitations and qualifications as that given to town boards of health upon the

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[1] Acts of Mass., 1871, Chap. 167, Sec. 2.

same subject, and, of course, with the same right of appeal. This construction of the statute preserves the general system provided by law unimpaired; it simply gives to the State board of health jurisdiction, whether concurrent with the town boards or exclusively, it is not material to this case to inquire, in cities and large towns to do what may be done in every town of the commonwealth by the local board of health; but we do not think that it was the purpose of the legislature, nor does the language of the act compel us to say that its effect is to deprive the party of that right of trial by jury to which the citizens in such cases have been accustomed for nearly two centuries. . . ." "There is a peculiarity in this proceeding which quite distinguishes it from the ordinary rules which govern appeals. The appeal to a jury does not vacate the order. It remains in full force till annulled or altered. If not annulled or altered, it still stands; if altered, it stands as altered. If the alterations made are absolutely impracticable, the order still stands just as if the original order had been made in the terms of the order as altered by the jury; and, if the original order had oontained the same regulations, we certainly could not say, as matter of law, that the order was void. At any rate, we could not say that it was void so far as the restrictions which it was competent for the board of health to make were concerned, whatever may be said as to any restrictions which it was not within their power to make, and whatever the board of health may do the jury may do, and with the same effect."

This diversity of opinion between the judiciary of Massachusetts and that of New York is more apparent than real, but illustrates the remarks made above as to the uncertainty of the common law, and the need of great care in preparing statutes relating to this subject, and also the difficulties in the way of making a board of health a final court of appeal.

The necessity for care in preparing a law on this subject will also appear from the following considerations: It is desirable that a municipal board of health, or its properly authorized agents, shall at all times have the right to enter into, or upon, any premises for purposes of sanitary inspection, and to call upon the police to aid it in the execution of its orders; but, on the other hand, the principle that every man's house is his castle, that is, that "no man's house can be forcibly opened, or he or his goods be carried away after it has thus been forced except in cases of felony, and then the sheriff must have a warrant," is, as explained by Lieber, one of the special means by which personal liberty is secured in Anglican communities, and this principle, together with that of the prohibition of general warrants, should be preserved as far as possible. The means by which the sanitary code is to be enforced should be distinctly stated in the code itself.

It is also desirable that the act should define clearly the meanings in which such words as the following are used, viz.: Persons (to include corporations); owner (to include agent or trustee); land, drain, sewer, street, house, report, permit, light, adulteration, etc.

In attempting to remove a municipal health department as much as possible from the arena of politics, the question will arise as to whether it is to have direct charge of such matters as street-cleaning, removal of garbage, etc. It is extremely difficult, if not impossible, to impose such duties upon a board of health without injuring its character as a scientific and expert commission and burdening it with a patronage which it is not desirable that it should possess; and, on the other hand, it seems desirable, for the sake of promptness and efficiency, as well as to avoid multiplication of officers and division of responsibility, that the board of health should have some control of such matters.

No general rule can be laid down on this subject, but it would appear that usually the details of such work had better be left to the police authorities; while the health authorities should advise as to what should be done, and inspect and report upon the methods of performance and the results obtained.

If a municipal board of health be properly constituted, so that its relations with the majority of the medical profession are harmonious, it is extremely desirable that it should be charged with the general supervision of all medical charities; such as hospitals, dispensaries, and asylums; which receive support entirely or in part from the public funds, and that it should have power to require from them such reports and statistics as it may deem necessary; in fact all public medical attendance furnished to the poor might well be under the supervision of the sanitary organization, and even private medical charities should of their own accord invite inspection by its officers, and furnish to it statistics and reports.

A municipal board of health should also be charged with the sanitary inspection of all schools, public and private, and should have power to direct the abatement of any nuisances in them, to prevent overcrowding, and to decide under what circumstances a child shall not be permitted to attend the school—as, for instance, how long a time must elapse after an attack of measles or scarlatina before the patient shall be allowed to rejoin his playmates, and this not only in general, but in particular instances.

In all health boards, municipal, State, or national, it is important to secure a certain degree of continuity of membership, and especially is this the case in this country, where there are as yet very few specially trained sanitarians, and where those appointed must therefore necessarily spend some time in acquiring by experience the knowledge and ability to properly perform their duties. Hence, the period of service may well be from three to six years, and it should be so arranged that only a minority of the board shall go out of office at one time. The continuity of the board should also be secured by the keeping a full, and accurate record of its proceedings, with files of all correspondence, reports, etc. So important is this that some means should be provided whereby an inspection of these records and files shall be made, both at stated and irregular intervals, by some authorized and properly qualified agent of the appointing power independent of the board itself.

It should also be observed with regard to these records and reports that many of them should be considered as strictly confidential; in fact, unless it is well known that this is the case, it will be found almost impossible to secure from the medical profession some of the reports which are most essential and important.

What a board of health needs, and should strive above everything else to obtain, is prompt, full, and accurate information with regard to all matters under its charge, and it should use all means to encourage and stimulate the furnishing of such information, and in particular it should take the greatest care to prevent the use for private purposes of any reports made to it. Nor should the board by any means confine itself to information furnished by its own special, regularly salaried agents.

When a special subject requires investigation, it should endeavor to secure skilled labor: to get the man who probably is best fitted to carry out the research, and, above all things, to avoid, not merely the making of political appointments, but the incurring the suspicion of making such.

Its success will depend largely upon its relations with the better class of the medical profession, upon its securing the interest and co-operation of the leading physicians of the community who form the tribunal by which it will be judged.

The branches of medical knowledge with which it is most desirable that the health officer should be familiar are not those most nearly related to therapeutics, and the most distinguished practitioner of a neighborhood may not be by any means the person best qualified for a sanitary appointment, although tact and good sense are equally necessary for both.

But the health officer should be a good diagnostician and pathologist; he should be thoroughly qualified to fill the position of coroner, and probably it would in most cases be best to merge the duties of that office with his own.

And finally, in the words of Dr. Letheby: "There are many occasions, especially those of secondary importance, which occur most frequently, when an officer of health acts as an intermediate agent between the public and the administration, when his functions are those of a conciliator, when he has to listen to complaints of grievances on one side, and angry recriminations on the other.

"Judging, however, solely of the question of public safety and public health, and disregarding or calming down the animosities with which the complaints are too often beset, he should endeavor to decide in such wise as to satisfy the demands of the administration, as well as the reasonable objections of opponents. His advice, indeed, should be such as will not only meet the requirements of the case, but will also gain the assent of every good citizen. Above all, he should even oppose himself to all vexatious and litigious proceedings, to all unfounded misapprehensions, and to all exaggerated views of public sanitary questions; for nothing is more likely to impede the progress of knowledge, and to bring the functions of his office into disrepute, than the unchecked fancies of visionary alarmists, or the still more mischievous opinions of sensational agitators."[1]

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[1] H. Letheby: On the Qualifications and Duties of an Officer of Health, London, 1867, 12mo, p. 19.

Much of what has been said with regard to municipal or local boards will apply also to State boards of health.

The State board of health should be the central supervising authority, having much the same relations to local boards that the local board has to the householder.

Its functions may be classed roughly as follows:

1st. To promote the organization of local and municipal boards.

2d. To obtain medical and vital statistics.

3d. To investigate the causes of undue sickness and mortality, as indicated by these statistics.

4th. The removal of these causes, acting as far as possible through the local sanitary authorities.

5th. The supervision of the hygiene of State institutions, such as prisons, insane asylums, workhouses, etc.

6th. The supervision of quarantine.

There are now in existence in the United States nineteen State boards of health. For the details of legislation with regard to these, reference may be made to the discourse of Dr. H. I. Bowditch on "Public Hygiene in America," Boston, 1877, 8vo; and more especially to the appendix by H. G. Pickering, entitled a Digest of American Sanitary Law.

Very much of this legislation as regards State boards of health is, however, merely theoretical, and has no actual practical application.

The code looks well on paper, but has no real force, and from an examination of existing statutes only, it is impossible to tell what the real powers and duties of the State sanitary organizations actually are. Of the nineteen State boards of health now existing, more than one-half have no sufficient means or powers to perform the duties imposed on them by statute.

It would be useless, therefore, to comment on the differences in these organizations, but some of them are so peculiar as to merit a brief notice.

The State Board of Health of Massachusetts, which is the most firmly established of all, has the peculiar power of acting as a court with regard to nuisances throughout the State, and until recently its decisions were considered as final. At present the party upon whom the order of the board of health is served has the right of appeal to a jury, as above referred to; but while the appeal is pending the order of the board remains in force. The members of the board serve without compensation, and the efficiency of the system depends mainly on the secretary.

The State Board of Health of Alabama, by Act of 1875, is made identical with the State Medical Society. This organization has not yet been at work long enough to show its capabilities for good or evil, nor indeed has it been intrusted with more than advisory powers, being in fact very much like a French departmental *conseil de santé.*

It is claimed for it that it is a self-perpetuating corporation, composed exclusively of medical men, which defines its own duties, directs its own operations, and appoints its own agents, and is thus placed beyond the control of local and political influences, and that it secures to the State the largest amount of the best work at the least risk and smallest possible expenditure of money;[1] and in this there is much truth, but so long as its powers are merely advisory, no specially good results can be expected, and, so far as economy is concerned, this is by no means identical with cheapness. The State Board of Health of North Carolina was organized on the same plan, and allowed $100 for its yearly expenses. When Alabama or North Carolina allows to its State Board of Health, as at present constituted, about $20,000 per annum for expenses, and confers on it such legislative, executive, and judicial powers as were given to the Metropolitan Board of Health of the City of New York, it will try a very interesting experiment, the results of which, whatever they might be, would be well worth the annual appropriation for two or three years.

The State Board of Health of Illinois has more extensive duties and theoretical powers than any other similar organization in this country. It is composed of seven persons, who hold their office for seven years, and it is declared by the statute that "they shall have charge of all matters pertaining to quarantine, and shall have authority to make such rules and regulations, and such sanitary investigations, as they may from time to time deem necessary for the preservation or improvement of the public health, and it shall be the duty of all police-officers, sheriffs, constables, and all other officers and employees of the State to enforce such rules and regulations so far as the efficiency and success of the board may depend upon their official co-operation." If it were not for the last sentence, this would certainly seem to give the board almost unlimited power; but this clause is of very doubtful meaning, since it does not appear who is to decide as to when the "efficiency, etc., depend," etc.

Another peculiarity in the duties and powers of this board is shown in the following extract from a decision of Judge Williams, delivered at the October term of the Cook Circuit Court, in 1878, in the case of Nathan J. Aikin *v.* State Board of Health:

"It (the State board of health) is constituted, among other things, to have charge of medical practice and medical practitioners in this State, and it is its right and duty to have surveillance of the professional conduct of physicians by the language of the act of incorporation. Any persons guilty of unprofessional conduct may be by it refused certificates, and any persons having certificates who were guilty of unprofessional conduct may have their certificates revoked by the board. The object of the incorporation of the board is, among other things, to secure a higher professional standard in the medical profession. It is to exclude empirics and empiricism from the profession. The duties of the board are various, and the interests intrusted to its keeping affect all classes of the community, and affect them in the most vital points. The character of its duties is in part set forth in the second section of the act creating the board. 'The State board of health shall have the general supervision of the interests of the health and life of the citizens of the State. They shall have charge

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[1] See Annual Message of Peter Beyre, M.D., 1878, p. 8.

of all matters pertaining to quarantine, and shall have authority to make such rules and regulations, and such sanitary investigations, as they may from time to time deem necessary for the preservation or improvement of public health,' and all police-officers, sheriffs, and other employees of the State are required to enforce its rules and regulations so far as the efficiency of the board may depend upon their co-operation. Such a board must, from the necessity of the case, be vested with a large discretion. And, in the legitimate exercise of its discretions, it ought not to be, and cannot be, properly controlled by judicial tribunals. The duties of the board, with reference to the sanitary condition of the people, bring it into such relations to the medical profession as fit it to determine the necessary qualifications of its members, and to judge of the propriety or impropriety of their professional deportment. The law has devolved this and similar duties upon the board, and it has created no other corporation in the State for a like purpose, nor has it given to any State officer supervision over the board in the discharge of its appropriate duties and the exercise of its legitimate discretions. A physician may be guilty of unprofessional and dishonorable conduct, and not of criminal conduct. It would have been a work of supererogation in the law-makers to have vested the board of health with the supervision of the unprofessional conduct of the medical practitioner, if unprofessional conduct and criminal conduct were synonymous. As a citizen, the physician is, with every other citizen, answerable to the criminal laws, and as an alleged criminal is liable to be arraigned before our courts. It is only as a physician that he is liable to have his professional conduct inquired into and brought before the State board of health. The term unprofessional is therefore far wider than criminal. Many acts would be unprofessional that were not criminal; some acts that were criminal might not be esteemed unprofessional. What is professional conduct can only be determined by bringing the act to the professional criterion, and who so well qualified to judge of the proper professional criterion for the medical profession as a board constituted, as the bill shows this board to be, of seven gentlemen, five of whom are physicians, and a board created for sanitary purposes, and accustomed to sanitary investigation? The 'unprofessional' conduct which authorizes the board to exclude a physician from the profession does not, therefore, mean necessarily criminal or immoral acts, but such conduct as is inconsistent with the honorable practice of the profession; and, in judging of such conduct, the board of health has a wide discretion, and in its exercise courts ought not to interfere with it."

This decision has been appealed from, and the result cannot be predicted, but among observant sanitarians there is a fear that if matters take the usual course, there will be a reaction, and that the description of the course of public hygiene in England—viz., that it has consisted in taking three steps forward and two backward—will also apply here.

The act to establish the State Board of Health of Illinois must be taken in connection with the act passed at the same time to regulate the practice of medicine in the State, by which the board of health is given supervision over medical education, and acts as an examining board in issuing licenses to practise.[1]

Whatever may be thought of this provision, it certainly seems eminently desirable and proper that a State board of health should provide some machinery for examining and certifying to the fitness of candidates for positions as local health officers.

The result in Illinois has been that of 3,600 non-graduates, who were practising medicine in the State when the act went into effect, about 1,400 have left the State, or ceased to practise.[2]

By the tenth amendment to the Constitution of the United States, it is provided that "the powers not delegated to the United States by the Constitution, nor prohibited by it to the States, are reserved to the States respectively, or to the people." It is under this clause that, as has been shown by judicial decisions quoted above, the police power is reserved to the several States, and does not belong to the General Government, except as regards the District of Columbia ; and hence there are special difficulties in the way of giving any administrative powers to any central sanitary organization, such as a national department of health, health board, etc., even if it be considered desirable that it should possess such powers.

As it is important that the powers of the General Government should be clearly understood by those who are interested in congressional legislation affecting the public health, special attention is invited to the following extracts from judicial opinions, involving the general principles which determine these powers:

"The object of inspection laws is to improve the quality of articles produced by the labor of a country ; to fit them for exportation ; or, it may be, for domestic use. . . . . They form a portion of that immense mass of legislation which embraces everything within the territory of a State not surrendered to the General Government; all which can be most advantageously exercised by the States themselves. Inspection laws, quarantine laws, health laws of every description, as well as laws for regulating the internal commerce of a State and those which respect turnpike roads, ferries, etc., are component parts of this mass.

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[1] For details as to the working of these acts, consult the First Annual Report of the State Board of Health of Illinois, Springfield, Ill., 1879, 8vo.

[2] For further particulars as to the organization and powers of municipal and State boards of health, consult "The Sanitary Code for Cities," prepared by Henry G. Clark, M.D. Revised and adopted by the National Quarantine and Sanitary Convention. Revised reprint, Boston, 1865, 8vo.

Digests of Statutes and Ordinances relating to the Public Health, Boston, 1873, 12mo.

Rules and Regulations recommended by the State Board of Health of Michigan for Adoption by Local Boards of Health, Lansing, 1875.

Metropolitan Board of Health, Code of Sanitary Ordinances, New York, 1867, 8vo.

Sanitary Legislation in England and New York, New York, 1872, 8vo.

Plan of an Act to establish State Board of Health, Public Health Reports, Am. Pub. Health Assoc., Vol. II., N. Y., 1876, p. 526.

"No direct general power over these objects is granted to Congress; and consequently they remain subject to State legislation. If the legislative power of the Union can reach them, it must be for national purposes; it must be where the power is expressly given for a special purpose, or is clearly incidental to some power which is expressly given.[1]

"That a State has the same undeniable and unlimited jurisdiction over all persons and things, within its territorial limits, as any foreign nation; where that jurisdiction is not surrendered or restrained by the Constitution of the United States. That, by virtue of this, it is not only the right, but the bounden and solemn duty of a State, to advance the safety, happiness, and prosperity of its people, and to provide for its general welfare, by any and every act of legislation, which it may deem to be conducive to these ends, where the power over the particular subject, or the manner of its exercise is not surrendered or restrained, in the manner just stated. That all those powers which relate to merely municipal legislation, or what may, perhaps, more properly be called, *internal police*, are not thus surrendered or restrained; and that consequently, in relation to these, the authority of a State is complete, unqualified, and exclusive.

"We are aware that it is at all times difficult to define any subject with proper precision and accuracy; if this be so in general, it is emphatically so in relation to a subject so diversified and multifarious as the one which we are now considering.

"If we were to attempt it, we should say that every law came within this description which concerned the welfare of the whole people of a State, or any individual within it, whether it related to their rights or their duties; whether it respected them as men, or as citizens of the State, whether in their public or private relations; whether it related to the rights of persons or of property, of the whole people of a State or of any individual within it; and whose operation was within the territorial limits of the State and upon the persons and things within its jurisdiction."[2]

In the case of the United States *v.* De Witt, 9th Wallace, p. 41, it was decided by the Supreme Court that, "1. The 29th section of the Internal Revenue Act of March 2, 1867 (14 Stat. at Large, 484), which makes it a misdemeanor, punishable by fine or imprisonment, to mix for sale naphtha and illuminating oils, or to sell or offer such mixture for sale, or to sell or offer for sale oil made of petroleum for illuminating purposes, inflammable at less temperature or fire-test than 110 degrees Fahrenheit, is in fact a police regulation relating exclusively to the internal trade of the States." "As a police regulation, relating exclusively to the internal trade of the States, it can only have effect where the legislative authority of Congress excludes, territorially, all State legislation, as,

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[1] From writings of John Marshall. . . . . upon the Federal Constitution, Boston, 1839, p. 300.

[2] From Reports of Cases argued and adjudged in the Supreme Court of the United States, January Term, 1837, by Richard Peters, Vol. XI., Philadelphia, 1837. "The Mayor, Aldermen, and Commonalty of the City of New York, Plaintiffs *v.* George Miln," p. 139.

for example, in the District of Columbia. Within State limits, it can have no constitutional operation."

The powers of the General Government to legislate for the protection of the public health of the whole country have been more especially discussed in connection with various proposals which have been made for the establishment of a national system of quarantine.

It is claimed by some that under Par. 3, Sec. VIII., Act I., of the Constitution, which provides that Congress shall have power to regulate commerce with foreign nations and among the several States, Congress may prescribe the conditions upon which ships shall be allowed to land goods or passengers. But when the statutes relating to this subject are examined, it will be found that they recognize the principle that the quarantine and health laws of a State are supreme over any regulations which Congress may make respecting commerce.

In the Revised Statutes of the United States, Title LVIII. relates to the public health, and by the first section, which is the Act of 1799, the officers of the customs, of revenue cutters and of the army, are required to observe and aid in the execution of the quarantines and other restraints established by the health laws of any State.

The decision of the Supreme Court in the case of Gibbons *v.* Ogden (9 Wheaton), in alluding to this act, affirms its constitutionality as connected with "the acknowledged power of a State to provide for the health of its citizens." Or, in other words, as stated by Mr. Tucker, "Congress should sustain the health laws of the States, and may make provisions in aid of them, but not against them, or contrary to their purpose."[1]

Attention has been already called to the fact that judicial law is rather uncertain, but it would seem that under these rulings the General Government can do little in the way of compulsory legislation, which might interfere with the action of the several States to control their own sanitary affairs. It is possible that upon the ground of power to legislate with regard to commerce, it might establish some general system of quarantine and do something toward the prevention of the pollution of navigable streams; but it could probably only do this with such restrictions and exceptions as would make its action of little practical value, unless, indeed, it should resort to its right of eminent domain, and become liable for all damages, individual or municipal, which its action might cause. As regards quarantine, the power of the General Government to interfere, with good effect, under cover of its right to regulate commerce, is much restricted by the proviso in Par. 5, Sec. IX., Art. I., of the Constitution, which directs that "No preference shall be given, by any regulation of commerce or revenue, to the ports of one State over another." Under this clause quarantine regulations established by the General Government must be the same for the North Atlantic ports as for those on the Gulf, thus entailing much useless obstruction to commerce.

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[1] Opinion of Hon. J. R. Tucker, M.C., upon the Constitutionality of Quarantine Laws, in Reports and Resolutions relating to Sanitary Legislation, presented to the Am. Pub. Health Assoc., Cambridge, 1878, p. 8.

It is possible that in the future a constitutional amendment may confer upon Congress the necessary authority to prescribe and enforce measures for the preservation of the public health; and it is evident that with regard to quarantine, external or internal, the pollution of streams, and, in some cases, the securing of good drainage and a pure water-supply, centralization and a certain degree of uniformity are essential to securing the best results; but at present we can only look to the action of the individual States.

Upon the principles above laid down as to the duties and powers of municipal and State boards of health, and of the General Government, it does not seem desirable to burden a national board of health with legislative, administrative, or judicial functions, and it is believed that a board could be organized in such a manner as to produce nearly, if not quite, all the good results which could be hoped for from such an institution without in any way interfering with the rights of States or conflicting with the principles laid down in the judicial opinions above cited.

It is urged by Mr. Eaton that if the nation can properly exercise jurisdiction over every vessel and package of merchandise in navigable waters—can, through the census, make minute inquiries into the private affairs of every individual—can collect and publish the signs of the weather, tax for purposes of education, or seize private property for the public benefit—"how can it be denied that it is the right and the duty of the General Government to bring the diverse elements of its sanitary jurisdiction, as far as practicable, under one efficient board, which shall act in harmony with the health boards of the several States, and gather, arrange, print, and send all over the Union those records of the origin, cause, and progress of disease and death: those instructive and admonishing statistics of vitality and progress which measure the peril and the possibilities of commerce, which illustrate the power and the morality of a nation, which are the measure of our claims to the greatness to which we aspire and of our own fidelity to the religion which we profess." [1]

All this is certainly true so far as regards the collection of information, whatever may be thought of other matters.

No one would deny that the General Government can properly create an organization for the purpose of collecting and diffusing information on sanitary matters; but comparatively few understand how much real power and influence such an organization might acquire without having the slightest legal authority to enforce any of its recommendations.

The passing of sanitary laws, and the granting to a certain department the power to enforce these laws, will not ensure good public health unless the public at large supports those laws intelligently, and it can only do this through State and municipal sanitary organizations. The General Government might do much to promote the formation of such organizations, and to assist them in various ways. For instance, it might follow

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[1] From Public Health Reports and Papers, Vol. II., N. Y., 1876: The Essential Conditions of Good Sanitary Administration, by Dorman B. Eaton, LL.D., p. 514.

the plan, pursued in Great Britain, of refunding a certain portion of the expense connected with the management of a State board of health, if organized in a certain way, and if the State board undertakes to furnish certain reports and statistics for the information of the central board. It is upon this principle of subsidizing important interests without undertaking to directly control them, that the United States has promoted education, the construction of railroads, etc., and that it now proposes (during the coming year, 1880) to promote the gathering of important statistical information, by the several States, in the census.

By the "act to prevent the introduction of infectious or contagious diseases into the United States, and to establish a national board of health," approved March 3, 1879, the first step has been taken in the direction above indicated.

The act provides for a national board of health, to consist of seven members, appointed by the President, and of four officers detailed from the Medical Department of the Army, Medical Department of the Navy, and the Marine Hospital Service, and the Department of Justice respectively. No definite term of Office is prescribed, the Board being essentially provisional in character.

The duties of the board are "to obtain information upon all matters affecting the public health, to advise the several departments of the government, the executives of the several States, and the Commissioners of the District of Columbia, on all questions submitted by them, or whenever in the opinion of the board such advice may tend to the preservation and improvement of the public health."

The board is also directed to prepare a plan for a national public health organization in conjunction with the National Academy of Sciences, and after consultation with "the principal sanitary organizations and the sanitarians of the several States of the United States, special attention being given to the subject of quarantine, both maritime and inland, and especially as to regulations which should be established between State or local systems of quarantine and a national quarantine system."

Many of the reasons which may be urged for the establishment of a national board of health in the United States will also apply to the establishment of some form of international health organization which shall serve for the collection and centralization of information, and for its publication upon some uniform plan, and also to some extent for the prevention of epidemics. The principles upon which such an organization should be established do not differ materially from those indicated for a national board of health for the United States; the relations of the civilized nations of the earth to each other in regard to this subject being very analogous to those of the several States to the Federal Government.

The greatest obstacle to the formation of such an international organization has been the fact that the United States alone possesses no central sanitary authority by which it could enter into relations with such a body, while her commercial relations are such as to make it almost indispensable that she should be a party.

In view of the difficulties in the way of obtaining satisfactory legislation upon sanitary matters, and the ever-present danger that the officials to be charged with the execution of State or municipal health laws may be unfit for such position, it is worth noting that some of the benefits of co-operation may be obtained, and the dangers and difficulties of legislative interference avoided, by the formation of sanitary protection associations, as has been done at Edinburgh and at Newport, R. I. These associations are essentially mutual insurance companies, and although the main object of those just referred to is to secure thorough preliminary and periodic inspection of the habitations of the members with reference to drainage, plumbing, etc., yet the principle may easily be extended; and it would be quite possible to organize a life insurance company upon the same plan—a company which should not merely accept the usual chances of mortality, but should, as a matter of profit, attempt to reduce the mortality rates of its members, by employing skilled officers to do such work as is contemplated by the associations just referred to.[1]

Finally, it may be observed that while education of the people in hygienic matters is a necessity, and while the sanitarian must not in his practical work go beyond the point in which he will be supported by public opinion, since it is useless to prescribe remedies which will not be taken, yet, on the other hand, the people often wish what they are told they wish, and legislation is itself a powerful means of education.

But to secure true progress in hygiene, those already skilled must acquire more skill; and those who are leaders, more knowledge. Those who are charged with the care of the public health are responsible, not only for possessing existing knowledge, but for the increase of knowledge; and they may never "rest and be thankful, for the ancient Sphynx meets them at every turn, and her demand never ceases: Read me my riddle, O! man, and I will be thy slave; neglect it, or fail, and thou shalt surely be devoured."

The following lists of works relating to the general subjects of hygiene and State medicine are the result of a selection from a much larger number of titles. It will be understood, therefore, that they are by no means a bibliography of the subject. Works relating to special subjects are not given here. Only the last edition known to the writer is noted, and the titles are given as briefly as is consistent with the identification of the work.

The third section especially is incomplete, since almost every country and city in Europe has published sanitary ordinances and reports, but the majority of them have but a temporary and local interest.

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[1] For details consult The Edinburgh Sanitary Protection Association, San. Jour., Glasgow, June, 1878, p. 113; and The Sanitary Protection Association of Newport, R. I., 7 pp., 8vo, a circular issued by the Society.

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PART I.

INDIVIDUAL HYGIENE.

INFANT HYGIENE.

BY

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INFANT HYGIENE.*

The Newly-Born—Care of Respiration and Circulation.

NORMAL respiration and circulation ought to be immediately established after the child is born. The whole chapter of asphyxia cannot be considered here, but Landau's essay on "The Melæna of the New-Born, with Notices on the Obliteration of the Fœtal Blood-Vessels," proves that, in many instances, but little attention has been paid to the subject. He explains its occurrence by the rupture of an artery or vein, in a round ulcer of the stomach or duodenum, which has not originated during intra-uterine life, and not in consequence of inflammation, but has been produced by disturbances of the circulation dependent upon insufficient respiration. The impediment to respiration consists in aspiration of mucus, in pressure during the process of parturition, and, finally, in congenital muscular debility. Circulation suffers in consequence; from a secondary thrombus of the ductus Botalli, or from a primary one near the spot where the umbilical vein is ligated, an embolus is carried off, and becomes the source of hemorrhage. It is a peculiar fact that the newly-born afflicted with melæna are mostly of the female sex. It is possible that this circumstance is to be explained by the relative smallness of the blood-vessels in the female. Even in such cases, where no material causes are found, it is still to be presumed that there are disturbances of circulation, dependent upon increased pressure, in the venous system. If that be true, the direct inference is that new-born children should be made to cry aloud. Moreover, it is proper that protracted sleep, in *feeble* children, should be prevented, and that they should be compelled to cry occasionally. When the infant does not cry, both respiration and circulation remain defective, and immediate resort must be had to the usual means recommended in the text-books on obstetrics, such as external irritations, beating, alternation of warm and cold bathing, swinging, etc. In cases in which all these means fail to establish respiration and circulation, Pernice, myself, and others, and lately Lauth, have resorted to the use of the electrical current. Lauth describes three cases: one with permanent, and one with temporary success. He used dry electrodes along the vertebral column, the brachial plexus, and also over the phrenic nerve.

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* The material used in the present article is drawn largely from the author's contribution to the first volume of Gerhardt's *Handbuch der Kinderkrankheiten*, Tübingen, 1877.

Each application lasted two or three minutes, and in the intervals he aided recovery by insufflation. But this much must be said with reference to the use of the electrical current, that a continuous application for two or three minutes is decidedly too long. For my experience has taught me that the irritation turns into over-irritation and paralysis, and the effect produced is directly the reverse of that desired. Neither have I been able to convince myself, contrary to the theoretical and practical postulations of many authors, that the application of the electrodes over certain nerves, —for instance, over the phrenic nerve or over the diaphragm—will yield special results. This is particularly true when the electrodes are dry, for there is no possibility of their effect penetrating the skin. The effect will remain superficial. I am of the opinion that the momentary superficial pain yields the main effect. The application must be momentary, frequent, and not protracted. In a number of cases reported in the proceedings of the New York Obstetrical Society, several years ago, I made the observation that, in the very commencement of the faradic treatment, respiration becomes deeper and more frequent, and the heart-beat is increased in frequency and strength. But when the electrode is not soon removed, the beat of the heart becomes slower, and the infant appears as though in a fainting spell, or in the condition of collapse. My rule, therefore, is to interrupt the treatment every few moments. Besides, it is very difficult to localize the current over small and deep-seated localities. I have always feared that the smallness of the territory upon which we mean to act gives but very few chances for a circumscribed application of the electrical current. The correctness of this doubt has already been admitted, so far as the phrenic and the sympathetic nerves are concerned. For, as early as 1872, Ziemssen directed general attention to the fact that many symptoms, attributed to the influence of the sympathetic, did not depend upon it alone: as, for example, dilatation of the pupils, which, according to Bernard and Westphal, can result from any strong irritation of any of the sensitive nerves. Galvanization over the neck, with a very strong current, makes a very marked impression upon sensitive nerves. It is therefore to be accepted, with Fischer, that the so-called local application of either the faradic or the galvanic current, in the region of the neck, is not local at all, but that the sympathetic, the pneumogastric, the phrenic, the superficial sensory, and the motory nerves are excited at one and the same time. Still the electrical treatment will be successful in both asphyxia and the debility of the prematurely born. The latter are to be treated, besides, like sick infants, and it is therefore necessary to warm them, artificially, between hot cloths or bottles, or in front of the furnace register; they may require stimulating enemata, and now and then I have seen good results from the subcutaneous injections of brandy. Ahlfeld has lately shown what may be accomplished with infants born prematurely. He refers to D'Outrepont, who preserved the life of an infant thirteen inches in length and weighing one and a half pounds; also to Kopp, who saved a child that weighed two pounds, and was eleven inches in length; also to a case reported by Redmond, in which the infant weighed one pound three ounces and a half and was thirteen inches in length. He also gives two cases of his own: the *first* was a child, born in the twenty-eighth or twenty-ninth week of intra-uterine life, which was 39 ctm. in length, and could not nurse until it was a few weeks old; the *second* was an infant that measured 39 ctm. in length five weeks after its birth, and at that time weighed 1,450 grms. He recommends, as the most efficacious means of preserving the life of such children, warm bathing, wrapping the infant in cotton, and the frequent administration of proper food, that is, hourly feeding, even though it be necessary to wake up the child for that purpose.

The Umbilical Cord—Anatomy and Changes—Treatment of the Normal and Pathological Conditions.

As soon as the new-born child has given two or three vigorous cries there is no longer any reason for delaying the ligation of the cord. The circulation in the umbilical vessels or in the placenta has no further influence upon the child the moment its own pulmonary circulation has been awakened to normal activity. It is useless to wait for the cessation of pulsation in the cord, which is sure to become weaker and weaker whatever change takes place in the child's circulation. The practice of emptying the contents of the umbilical vein into the child's body may be excused in a puny, ill-developed newly-born infant, but is reprehensible, as a rule, because of the increased stress imposed upon the child's circulation, which, right after birth, is so easily disturbed.

In every case of asphyxia we should ligate as quickly as possible to be able to make efforts to resuscitate. We can look for no aid in the simple fact of the child's connection with the placenta, which has already begun to be detached from the uterus. The ligation is made with a cord not fine enough to cut through the tissues, nor so thick as not thoroughly to compress the vessels. It is applied from three to six centimetres from the body. A few centimetres nearer the placenta, a second ligature is applied, and between the two the cord is divided. The child's end of the cord is then wrapped loosely in a piece of fine old linen, and laid upon the left side of the abdomen. The whole is then covered with a broad strip of linen, and over that, a bandage, something wider than a hand's breadth, is passed once and a half or, at most, twice around the body. This is drawn just tight enough to prevent its slipping, and secured with a band or with safety pins. The bandage may be of flannel or cotton, and should be sufficiently wide to reach from the axillæ to a little below the crests of the ilia. This of itself serves as a comfortable and convenient article of clothing during the first few weeks of life. The entire dressing should be changed at least once a day.[1]

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[1] A very animated discussion of the question of ligation of the cord has arisen in connection with cows and mares. It was observed that the lower animals, both domestic and wild, have no wet-nurses, nor do they use ligatures and shears. And inasmuch as we hear of no hemorrhages from the cord in these lower creations, we ought not to expect that the neglect of ligation would be followed by any such conse-

The umbilical arteries are large and thick, especially in the vicinity of the navel, both inside and outside the abdomen. Within the abdominal cavity they are dense and of yellowish red color; outside the abdomen they are softer and paler. Their muscular fibres are mostly circular; a few are longitudinal. Where both occur, the longitudinal are external. These fibres are prolonged into the adventitia, and are especially marked within the abdomen in the neighborhood of the ring, but further in are less well-developed. In the umbilical cord itself massive bundles of muscular fibres extend from the adventitia to the endothelium. It is only near the navel, and especially within the abdomen, that we have any mingling of elastic tissue. An intima proper is developed only in the vicinity of the iliac artery. We thus have explained the marked influence which the rigor mortis of the severed cord exercises in preventing hemorrhage. The artery is contracted to 1½–2 mm., so that a fine probe can scarcely be introduced; the column of blood is coagulated, and outside of the navel-ring the artery is so narrow that no thrombus or but an insignificant one can form there. The action of the rigor mortis and the coagulation of the blood naturally react upon the intra-abdominal circulation. But this is not all. In the umbilical arteries there are certain prominences, extending in straight, diagonal, or irregular directions, which cannot be obliterated by stretching. They contain much elastic tissue. Dilatations occur also in the arteries, the result only of variations in the thickness of the walls. Moreover, there are longitudinal furrows in which the muscular layer is thinned, and also folds, especially within the umbilical cord, but there are no valves (Stravinski). The arteries which are stretched upon the placenta's part of the cord are more tortuous than elsewhere, growing smaller as they approach the placenta's border. (Neugebauer, 1858; Hyrtl, 1870.) Kleinwächter found the same characters in the arteries, whether the fœtus was carried to full term or not, while the veins, toward the end of fœtal life, became enlarged (placenta 10, cord 11.33 mm.[1]).

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quences in the young of the human family. The ligature has not only been declared useless, but even injurious. The well-authenticated instances of hemorrhages occurring where the ligature had not been applied or had slipped. are simply ignored. King recently asserted the ligature to be dangerous "by preventing the escape of blood from the umbilical veins, with consequent congestion of the liver" (?!). He claims, too, sometimes it is fatal, "by keeping the right ventricle distended" (?!). Instead, therefore, of tying and then cutting the cord, he advises its division close to the body after the arterial pulse has ceased. The division is effected by an écraseur or a dull pair of shears, and the contusion must be thorough and long continued. The idea, however, is not new. Old Faust, of Bückeburg, spoke of dividing the navel-cord in "a manner well pleasing to God," with "gnawing scissor-cuts." The facts are as follows: when the cord is cut and not tied, hemorrhages generally follow; when it is torn in a circular manner, they are still usual; but when it is torn off irregularly, there is frequently no hemorrhage whatever.

The above facts do not afford a complete solution of the question, and it is far better to be guided by discretion and prudence than to trust to mere chance.

[1] In long and heavy fœtuses and in boys the vessels are larger. Is that the reason why hemorrhages from the cord are so much more common in boys than in girls? (Grandidier, Jenkins, Ritter.)

The furrows and dilatations of the umbilical arteries have nothing to do with the arterial contraction; they are found after death distended and filled with blood. So they cannot be regarded from a teleological point of view. Stravinski, to whom I am mainly indebted for this description, observes further that the thickened portions of the walls are not always found at those points where we should look for the most effective contraction for the purpose of stopping the flow of blood. Therefore there is but one main factor that operates to stop the flow of blood, viz., the contraction of the powerful muscular apparatus in the vessels which are brought into play, partly by the rigor mortis, partly by the stimulating effect of the atmosphere and other influences acting upon the body of the infant and communicated to the umbilical arteries by reflex action. Still, it is probable that the strength or feebleness of this contraction; the frequency or infrequency of its occurrence; the favorable or unfavorable situation of the prominences; dilatations, thickenings, and furrows in the blood-vessels, which, though they do not entirely prevent the flow of blood, render the current slower, narrower, or irregular—all play a certain part, both in producing hemorrhage and in stopping it. Therefore, apply the ligature under all circumstances, notwithstanding the fact that the neglect to tie the cord is not always followed by hemorrhage. We may disregard such reports as that of Martin, who states that "they do not tie the cord in Java," and yet no hemorrhages occur. Under the influence of the warmth of the bed, or of the warm bath, the blood-vessels may again relax, the heart-muscle be excited to activity, and hemorrhage be apt to follow. Moreover, the fact should be borne in mind that vascular anomalies may occur. Hausmann reported three cases of unequal development of the umbilical arteries. In one case one of the vessels was very small, and terminated within the pelvic cavity on the posterior wall of the bladder, close by the umbilical cord. The other artery, together with the hypogastric and common iliac, was enlarged.

After division of the cord, its spiral twist is obliterated. The vessels appear retracted, since, under the pressure of the ligature, the gelatinous matter of the cord is somewhat pressed forward. Desiccation begins at once, commencing at the ligature, and extends rapidly toward the abdominal wall. The rapidity of desiccation will of course depend upon the thickness of the cord. The color is altered, becoming at first bluish, with the vessels showing through, and then gradually grows darker and blackish.

The form of the cord is altered, partly through shrivelling up, partly by the external pressure. It becomes flat and parchment-like, and is a little thicker near its cutaneous portion, where the line of demarcation is forming. This line of demarcation appears almost always on the day before desiccation is complete. Of Tschamer's 100 cases this was true in 85; in 15 cases the line did not appear until after complete desiccation, which occurred in 3 cases on the first day, in 24 on the second, in 71 on the third, and twice on the fourth. The line of demarcation is usually narrow, only a line in width. But where the cord is large, or where the skin is prolonged into the cord for a considerable distance, it is wider. In such cases, there is not unfrequently a pronounced inflammatory reaction. There is usually but little suppuration. Finally, after undergoing granular disintegration, the desiccated cord drops off. At the last it is held only by the vein. It generally falls on the fourth or fifth day, sometimes on the sixth (once in Tschamer's 100 cases), and occasionally on the seventh (twice in 100, according to Tschamer). Doubtless it may fall even later. I have seen it remain till the eleventh day, and E. Loewensohn saw it remain till the thirteenth day.

The extent of the remaining wound and the rapidity of healing will, under ordinary circumstances, depend upon the thickness of the cord and the severity of the process of demarcation. The cutaneous portion of the cord quickly retracts, granulations spring up rapidly, and the wound is soon cicatrized. At first the scar is of a pale red color, but gradually becomes lighter. At first it is linear, afterward angular, and finally, in consequence of the retraction of the umbilical vessels, the peculiar form of the navel fossa is produced, with its greater arch above, where the arteries retract, and the lesser below, corresponding to the vein. In the centre can be seen the remains of the vessels in what is known as the "vascular navel."

The surface, as a rule, is quite dry a few days after the fall of the umbilical cord, and cicatrization advances without interference. This normal course may be disturbed by friction of the part, local irritation, or by infectious influences. E. Loewensohn found that the inflammatory redness disappeared from the surface by the fifteenth day, but, by stretching open the navel fossa, he found it still red and covered with a serous or purulent fluid until the twenty-first day. Sometimes it was completely healed in ten days, though he has known it to require as much as forty-one days. His observations were made in the Foundling Asylum of Moscow, where it is not unlikely, for obvious reasons, that the healing process may have been unusually delayed.

Whenever the secretion appears to be unduly increased or the inflammatory redness greater than usual, lukewarm astringent solutions of zinc, lead, alum, or creasote are indicated. Bismuth in powder, salves of zinc, or alum, or oxide of zinc dusted over the part, are useful applications. In seasons of epidemic erysipelas or diphtheria such applications should be made without delay; for, under these circumstances, it is far better to do what may be superfluous than to neglect what is perhaps of very serious importance. The perchloride of iron should, under all circumstances, be used with caution. If the case is a trifling one, a simpler application will answer, and, where the secretion is abundant, the iron may do harm. Roth lost a child by septicæmia after having made an application of chloride of iron for hemorrhage from the cord. It is very common to see septicæmia proceed from the uterus or from a lacerated vagina to which chloride of iron has been applied to stop hemorrhage. In all of these cases the thick layer of coagulated blood, by preventing the escape of the foul secretions, facilitates absorption of septic substances.

Should the healing of the umbilical stump not proceed rapidly, the navel fossa must be examined frequently and applications made as above described. Not unfrequently, after a time, a growth of exuberant granulations, known as "fungus," will be found in the umbilical fossa. These growths are sometimes sessile, though occasionally they are slightly pedunculated, and show a disposition to grow rapidly. Of six fungi of this sort, described by O. Kuester, five were simple granulomata without epithelial covering; another was half covered with epithelium, and showed a distinct horny layer and rete Malpighii. The treatment of these granulation growths is very simple. Touching them with alum, an occasional application of the nitrate of silver, or once a day touching them with a drop of the chloride or subsulphate of iron, or sometimes the application of the ligature, suffices to hinder their further growth and to gradually destroy them.[1]

Examination of the Newly-Born.

The body of the infant should undergo rapid and exact examination immediately after its birth. Malformations of the extremities and of the face, spina bifida, hypo- and epispadias, imperforate rectum or anus, can be easily detected. It is especially important to examine the head very carefully. Now and then, particularly after a difficult labor, there can be found fissures chiefly upon the frontal and the parietal bones. There may also be arrests of development, as, for instance, encephalic or meningeal hernia. The latter are of very great importance. The more so because there are forms which, especially in the temporal and the orbital regions, may give rise to great mistakes in diagnosis. This subject, being mainly of pathological interest, may here be dropped. But there is another class of changes which is of vast importance, such as obliquities and flattening of the cranial bones, with considerable asymmetry, and erosion, or other lesions of the skin resulting from pressure either of the promontory or of the forceps. Still it must not be forgotten that there are deformities of the head which cannot be ascribed to disturbed processes of parturition. Hecker has lately laid stress upon the fact that there are certain forms of the head which are not the consequence of face presentation, but rather its cause.

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[1] Kuester has also described a navel fungus occurring in a three-months-old child, the centre of which consisted of dense connective tissue, with closely packed round cells outside of it. Throughout the entire mass, glands were embedded with cylindrical epithelium, the cells of which were closely packed, simple in nature, and measured 0.024 mm. The epithelium of the tumor between the glands was disposed in a single layer of cubiform cells. This fungus, therefore, was probably the remains either of the allantois or of the ductus omphalo-mesentericus. The former might be inferred from the facts demonstrated by Ahlfeld, Zini, Ruge, and Sabine, which point to the presence of a fourth canal in the umbilical cord. In favor of the latter is the fact of the not very uncommon occurrence of well-marked traces of canals still remaining open which are capable of being traced into the intestinal tract. Twice in my life have I seen such tumors, evidently the remnants of the omphalo-mesenteric duct.

Tumefactions about the head are frequent and interesting; sometimes they are small and œdematous only. If so, they will disappear within twelve or twenty-four hours. Even in those cases in which there are numerous punctate hemorrhages in the œdematous tumefaction, the swelling disappears after a short time. Actual cephalohæmatomata are more grave in character, because now and then they can be more dangerous, and have a longer duration than the simple swellings just mentioned. If the seat of the cephalohæmatomata is simply extracranial, and there is no complication with intracranial hemorrhage, the only remedy required is time. The tumor will steadily, but slowly, increase in size for several days. Weeks, and sometimes months, are required for its absorption, and the progress will be favorable if the practitioner do not yield to the temptation of disturbing the process of gradual absorption by resorting to therapeutical measures. If the tumor is left entirely alone, no anomaly will remain behind. These cases are not so grave as they at first appear. If the hemorrhage be considerable and the periosteum be removed over a large surface, it will result in slight asymmetry of the cranium in consequence of new-formed bone. The rule is, however, that all changes of this kind will after a time entirely disappear. Even marked asymmetries of the cranium, resulting from more important pathological conditions, have a tendency to disappear in the course of months or years. Thus I remember but a single case of so serious an affection as craniotabes, in which there remained during life a very moderate flattening in the right occipital region.

As far as the mouth is concerned, malformations may render nursing difficult, and sometimes impossible. The muscular debility which, now and then, prevents the infant from nursing its primiparous mother, but permits it perhaps to draw milk from the breast of the multiparous woman with better-prepared nipples, I shall speak of at some other place.

Simple, uncomplicated hare-lip prevents nursing only in feeble children, as long as the alveolar processes do not complicate the fissure in the lip. Nursing, however, is completely prevented by hare-lip attended with cleft palate. An unusual length of the soft palate does not prevent nursing to such an extent as does undue shortness. In the latter case, no vacuum can be formed in the mouth. I once saw, in an idiotic boy, a soft palate, which was entirely transparent and immovable. There was absolutely no muscular tissue in it; and the movements of deglutition and articulation were very defective. For many months efforts had been made to improve the boy's articulation; yet, during all this time, his mouth had not been examined. Small defects in the hard, with large defects in the soft, palate are also important in their effect upon nursing.

So far as the sebaceous follicles along the median line of the palate are concerned, as described by Bohn, I have not seen them in a state of ulceration immediately after birth; but I have seen cases, at a little later period, in which nursing was rendered impossible by extensive ulcerations, which, in consequence of permanent neglect, or of maltreatment, had extended down to the bone.

Of cohesion of the lips in the median line I have no personal knowledge; but extensive lateral fissure I have met with. Now and then the tongue gives rise to incapability of nursing, either in consequence of a fissure or of macroglossy. In the latter case it is entirely indifferent whether it consists in an actual new formation of muscular and cellular tissue or of cystic degeneration. One such case was operated upon by Fairlie Clarke. This affection is the more serious, as, in macroglossy, we usually have to deal with idiotic children.

It has been frequently asserted that the *frenum linguæ* exerts a great influence upon nursing. The practice of cutting or tearing it dates from the period in which the mechanism of sucking was not understood. When there is the slightest motility of the tongue forward and backward, there can be no possibility of an impediment to nursing; but there will be an obstacle to articulation. Thus I have never seen any serious results arising either from shortness or from elongation of the frenum linguæ. The so-called "swallowing of the tongue," which was first alluded to by Petit and Levret, consists, however, in an unusual length of the frenum, which permits the tongue to be doubled upon itself, thus giving rise to a serious impediment to either deglutition or respiration.

Some days or weeks after birth, when cleansing the mouth is neglected, there will be *muguet*, which, now and then, is a serious impediment to feeding, and may render the weaning of the infant inevitable. This muguet may be dangerous, and sometimes it proves fatal, although the occurrence of the same affection in the œsophagus and stomach is very rare indeed. It is of very frequent occurrence in the mouths of very young infants, and in a number of instances is explained by the frequency with which pregnant women (according to Hausmann, 11 per cent.) suffer from the same affection in the vagina. The *oidium albicans* of the muguet of the infant is also the parasite in this affection of the vagina of the woman. Moreover, it is identical with the *oidium lactis*, which is found during the fermentation of milk. For that reason it is impossible to distinguish varieties. To prevent it, absolute cleanliness is usually sufficient. It is necessary to wash the infant's mouth very frequently, after every nursing or vomiting, with cold water; and it is also important to wash the nipple of the woman after every nursing. If drops of milk are allowed to remain upon the nipple, the result will be fermentation and local irritation. In fissures and under scabs there are deposits of bacteria and vibriones; and from these the mouth of the child is liable to be influenced. Just so the infant infects the mother. When muguet has first made its appearance in the nursling, it is usually sufficient to wash the baby's mouth with alkaline solutions frequently and thoroughly. It is not sufficient, however, to simply wet it; but the oidium, the epithelium, and the foreign substances which make up the deposits are to be rubbed off, until, in many cases, a small quantity of blood is visible. By so doing, not only old deposits will be removed, but the formation of new ones will be prevented.

Finally, the floor of the mouth should be carefully examined. Brandt found a *ranula* of the size of an almond in the median line of the mouth of a girl of four days. Her brother had a still larger one at the same age. In a girl of seven weeks he found a bilateral ranula, and one upon the left side of the mouth in a boy of three months. All of these cases were speedily cured by incision.

The elimination of *urine* is to be carefully noticed. Not rarely will the newly-born infant urinate immediately after birth, but sometimes hours pass, and even a day, before the bladder is emptied. Deficient excretion of urine may be the result of an insufficient allowance, to the infant, of water. In such cases it is temporary and unimportant. But now and then there is an actual affection of the kidneys, which prevents secretion or elimination. Soon after birth there is an accumulation of uric acid in the calices of the kidneys, which may prevent the excretion of urine. Now and then this gives rise to the formation of stones, which are sometimes found in very young infants. In forty post-mortem examinations, made upon infants under one year of age, I found renal calculi *six* times. This certainly cannot be the rule, but it shows what may be expected under extraordinary circumstances. At all events, copious drinking, occasionally of mild alkaline solutions, and warm bathing are indicated in cases of defective elimination of urine. The restlessness and screaming will be relieved with every micturition. The same observation can be made with reference to older children, who have violent, constant, and apparently inexplicable screaming spells. Those symptoms depend frequently upon the presence and elimination of gravel or renal calculi. Nor is this all; there are a number of cases in which the presence of uric acid infarctus is the first cause of nephritis, that disease being the immediate result of actual irritation or even real injury. In many a case apparent meningitis in very young children will, upon close examination, be found to be a case of nephritis. In one case, at least, which passed under my observation, there was apparent sclerema in the newly-born that was the result of, or perhaps, I might say, was complicated with, acute nephritis. In that instance the nephritis, without doubt, was due to the presence of copious deposits of uric acid infarctus.

The Nipples of the Newly-Born.

The nipples of the newly-born exhibit occasional changes, either immediately after birth or after some days; tumefaction, or secretion, is not very rare. Guillot reports as follows on his examinations of the latter: It occurred from the seventh to the twelfth day, after which it decreased and ceased. It was white, neutral, or alkaline, turned sour when exposed to the atmosphere, formed a serous and a cream layer on standing, and consisted of water, casein, fat, and sugar. Under the microscope there were spherical bodies of unequal diameter, translucent, and insoluble in ether. Schlossberger found alkaline reaction; the liquids looked like watered milk, did not coagulate under the influence of heat, but did so under that of acid or rennet; they contained much sugar, normal milk-corpuscles, no colostrum corpuscles, no pus. Genser examined the mammary secretion of a girl of fourteen days, whose mammæ were as large as a walnut each, and permitted the removal, by gentle pressure, of 3 grms. of liquid. Its specific gravity was 1.01986; it was strongly alkaline. The microscopical examination revealed corpuscles of fat and colostrum and cell detritus. Chemically it contained casein, 5.57; albumen, 4.09; sugar of milk, 9.56; butter, 14.56; salts, 8.26—altogether 42.95 per 1,000 of solid constituents. The percentage of salts corresponds better with that of blood (0.8) than with that of milk (0.4–0.5). In the salts there were muriatic, sulphuric, and phosphoric acids, sodium, potassium, calcium, magnesium, and traces of iron.

Synety's examination was mainly anatomical and microscopical. The histological and secretory character of the mammæ of the newly-born was very much like that of the woman, with none but the quantitative difference, and without difference as to sex. The superficial milk-ducts were obstructed with epithelium; toward the interior they dilated, and formed cavities with cubic epithelium and a liquid resembling colostrum. The latter may be absent in the mature infant, but not unfrequently it is met with in premature and still-births, though the mammæ exhibited but a rudimentary development. The secretion resembles that of the woman mostly from the fourth to the tenth day; the gland itself differs from that of woman quantitatively only. About that time the milk-ducts show diverticles and sprouting; not all of them yield a secretion but all carry a cubic epithelium. The secretion obtained by pressing the gland increases up to six or eight weeks.

Squeezing, however, must be avoided. It is barely possible that the glands can be squeezed out without any injury; but the rule is, the bringing on of irritation and inflammation. Suppuration in the infant, and mutilation of a mamma in the adult from that cause, I have seen a number of times. When there is an inflammatory irritation, water or lead-wash are indicated; where there is swelling with hardness without redness or pain, iodide of potassium and glycerine (1 : 2–6) externally, with or without extract of belladonna.

Angiomata on or very near the mammæ are not rare. The subject does not strictly belong here; but I will say that, as these nævi are apt to grow fast, and become destructive to the neighboring tissue, they ought to be destroyed soon in female infants. The safest means is the actual (galvanic) cautery.

Skin—Bathing—Temperature.

The first bath of the child and its bathing generally require great caution. The effect of the increase or diminution of bodily heat in the newly-born or young child presents many peculiar features. The statements of different writers with regard to the temperature of newly-born infants are on the whole pretty uniform. Occasionally, however, we meet with some discrepancies in the measurements, when the temperature is taken irregularly and unfrequently. Thus, J. Stockton Hough examined

14 children and again 13, of ages varying from 20 hours to 44 months, and found in—

5	children from	20	to	36 hours old	an aver.	temp. of	37.39° C.	(99.4° F.)
6	"	3	"	10 days	"	"	36.97° C.	(98.6° F.)
7	"	2	"	9 weeks	"	"	36.73° C.	(98.3° F.)
9	"	3	"	44 months	"	"	36.87° C.	(98.5° F.)

But we have plenty of facts that are more reliable. Juergensen generally found less regularity than in a maturer age, and less variation depending upon the time of day. Baerensprung found immediately after birth a rectal temperature of from 37.8° to 37.9° C. (100° F. to 100.4° F.), a little higher than in the uterus or vagina. He observed a fall of temperature of one degree, Centigrade, after the first bath, and during the first ten days a rectal temperature of 37.6° C. (99.8° F.) in the evening and 37.4° C. (99.4° F.) in the morning. In normal births, Wurster found the temperature of the newly-born child on an average 0.1° C. (00.2° F.) higher than the temperature of the vagina. (Gaz. méd., 24; Gaz. hôp., 17, 1870.) He also found that when there was an elevation of temperature in the vagina the bodily heat of the child was proportionately higher. M. Andral concludes, from twenty-seven measurements of the temperature in the infant's axilla and four measurements in the uterus, that the temperature of the newly-born child is generally above normal, seldom below (38.7° -38.9° C. [101.8°-102.1° F.]), corresponding to the temperature of the uterus, which is 0.1°-0.4° C. (00.2°-0.8° F.) higher. But it is only just after birth that the temperature shows this elevation. A half hour later it is rather below normal, and from the second hour is equivalent to the normal temperature of the adult. Andral's opinion is that the abnormally high temperature of the new-born child is due to the uterus, the temperature of which will be found a little higher. Had he taken his measurements in the rectum, however, and not contented himself with those obtained in the axilla, he would doubtless have found a difference the other way. Lepine took the temperature of one hundred children twice during the day in the rectum. Directly after birth he found the temperature 0.2° C. (0.36° F.) higher than in the vagina or rectum of the mother (37.5° C. [99.5° F.]), and for the reason, as he very properly states, that the latter are more liable to be cooled than the fœtus in utero. In the colder temperature of the air the temperature of the child falls for several hours (in weakly children to 33° C. [91.5° F.]), and after twenty-four hours becomes normal again. An interesting supplement to his observations is afforded by the temperatures as compared with the weight. When the weight of the child increased from the fifth to the eighth day, the temperature was 36.83° C. (98.4° F.); where the weight did not increase, it was 36.82° C. As a general rule, his temperatures are a little low, possibly for the reason, suggested by himself, that all of the children whom he examined lived under unfavorable conditions. H. Fehling made 1,200 observations upon ninety children; twenty-five examinations gave a medium temperature of 38.32° C. (101° F.) for boys, and 37.99°C. (100.4° F.) for girls, with variations from 37.6° to 38.9° C. (99.7°-102° F.) After birth there was a fall of temperature which passed away in from ten to twelve hours. Later there was a characteristic difference between the temperature of children born at maturity and in good condition (37.35° C. [99.2° F.]) and those born prematurely—two to six weeks before time (36.81° C. [98.3° F.]). Fever in the nursing mother had no effect upon the child's temperature.

My own temperature measurements, which have not been very numerous, were all taken in the rectum. I have occasionally found, directly after birth, a difference between the child's temperature, and that of the mother's vagina, in favor of the former. But, as a rule, the child's temperature sank in a very short time by 0.5-1° C. (0.19° F.-0.18° F.), and on the following day was normal, above 37° C. (98.8° F.). The cause of the fall in temperature had been correctly indicated by others. It lies partly in the imperfect circulation and, especially, the imperfect respiration, and in the decided chilling to which the child is exposed on entering the world. The feebler the child is, the longer will it be before the cutaneous temperature rises again. For this reason, as has been ascertained by examinations made in the axilla—as deceptive here as in many diseases where either the surface is very rapidly cooled or the cutaneous circulation is very sluggish—there is always a certain lowering of the temperature immediately after birth. The effect of a moderate degree of cold acting on the skin and exciting reflex action is beneficial. But if the cold is long-continued before the bodily functions are fully and regularly established, it can only do harm. Therefore, the newly-born child should not remain too long uncovered. The physician cannot watch the professional nurse too carefully, as she slowly, with great deliberation and with great show of wisdom, addresses herself to the work of oiling and soaping, washing, rubbing, drying, bandaging and dressing the child, till finally, its hands and feet blue with cold, and its cheeks sunken, its array is complete.

The child's bath should not be too hot. The immense number of deaths from trismus that occurred in the practice of the Elbing midwife (99 out of 380 deliveries) is a sufficient warning in this connection (Kehrer). On the other hand, it should not be below 32° C. (89.5° F.). Violent chilling of the skin at this early period of life, before the functions have become regular, should be carefully avoided. During the first few months the temperature of the bath should not be much lower, and always should be tested with the thermometer. We need not share J. Simon's fears "that the epidermis will be macerated by the warm baths;" that the children bathed every day will become pale, feeble, and relaxed, and "suffer from eczema;" although we must admit the truth of his zoölogical observation that "no other sucking animal regularly receives a warm bath." The fact should be remembered that the younger the child, the greater is the proportion of external surface to the cubical contents of the body, and that the immense number of sensitive nerve-filaments and capillaries expose the surface in the young infant to violent reflex manifestations. A long-continued cool bath will not be borne even by children of more advanced age. For this reason, cool or luke-warm baths act so quickly and effectively in the fevers of children. For, as already said, it is not upon the weight of the body that abstraction of heat or the subsequent reaction depends, but upon the relative extent of conducting and radiating surface.

When the child is a few months old, and during the hot season especially, the warm baths should be followed by a cooler one, or later even by a cold bath, with brisk rubbing. When baths proper are not given, but simple washing supplies its place, inasmuch as the whole surface is not exposed at once, cooler water can be employed. Brisk rubbing must not be neglected, and it should be done during the bath, when the baths are gradually being made colder. It serves both to excite the cutaneous activity and to constantly bring fresh water in contact with the body. In pathological conditions it is important to bear in mind that, when luke-warm or cool baths are given for the purpose of reducing the temperature, this object is always accomplished. But if the activity of the cooled skin is not restored again, the temperature of the interior of the body will be enormously increased while the skin remains cool. In such cases the temperature will fall rapidly when a warm or hot bath is given, with the effect of dilating the cutaneous blood-vessels, inciting external circulation and restoring radiation from the surface. The indication for so doing is mainly found in such cases as are liable to prove dangerous, and terminate fatally through the elevation of temperature only.

But these pathological and therapeutical questions do not concern us here. I insist only on this, again, that the bath of the young infant be warm (about 31° or 32° C. = 90° F.); about the end of the second or third year the temperature of the (short) bath ought to be about 23° or 24° C. (73°–75.5° F.). The warm bath of the young infant ought to be followed by a sponging off, or washing, with cooler water, before the final rubbing and drying. This is sufficient in the direction of hardening. The latter is desirable, but protection and safety more so.

There is but little to be said concerning general dietetic rules for the newly-born, such as are contained in the numberless text-books on diseases of children, or obstetrics. General physiological and dietetic principles suffice for the purpose of regulating the care of the very young. It is true that the young infant requires *more* care, but not true that it requires a different one. In regard to the above remarks on the treatment of the skin, this only may be added, that rapid changes of temperature are not well tolerated, and high and low temperatures both must be avoided. Besides, by regular and moderately warm bathing, the skin is kept in a sufficiently normal condition to reduce the number and severity of cases of intertrigo. Where it develops, nevertheless, lycopodium and starch act less beneficially than oxide of zinc or subnitrate of bismuth.

Clothing must be warm and comfortable. Feet and abdomen require keeping warm. Soft flannel, or merino, in summer, is indispensable among the articles of clothing. Nothing ought to press or constrict. Even in Germany they begin to acknowledge the fact that a baby's limbs and chest require a certain freedom.

The general rule of keeping a baby's body warm permits of but a single exception; and this refers to its head. It ought to be kept cool, and requires a hair instead of a feather pillow, or a folded-up sheet over the latter. Feather beds must be avoided altogether, except in the case of feeble or prematurely born infants, in whom it is often very difficult to preserve a uniformly warm temperature of the surface.

Infant Feeding.

During the years 1845–1864 the percentage of infants, under observation in the clinic of Prof. Stoltz, in Strassburg, when nursed by their mothers, was 19; that of infants raised by strangers, 87. Willemain compared the mortality of nurslings remaining with their mothers, while in prison, with that of infants raised on artificial food outside the prisons; the former was 19, the latter 43 per cent. Frank reports, for Munich, 2,804 deaths in the first year of life, in 1868; 2,539 in 1869; 2,986 in 1870. The percentages of those raised on breast-milk were 10.6, 16.1, 17.6; of those fed without, 89.4, 83.9, 82.4. E. Walser reports a death-rate of infants under a year of 499 per 1,000, in a country-town where breast-milk is withheld systematically; of 322 in a neighboring town where part of the babies are raised on the breast. The differences in the feeding in these two localities do not depend on necessity, but on custom only; and the fatal results of artificial and coarse alimentation might be avoided. Under less favorable circumstances are babies in industrial districts, where women are compelled to work in factories. In Zurich, Dr. Kleinmann found the infant mortality considerably larger in the industrial than in the agricultural neighborhood. Now, of all the deaths (1,922) in the first year of life, 40.89 per cent. were from digestive disorders, and 21.01 from respiratory diseases. In the second year of life there were 695 deaths, of which 9.06 per cent. were of diseases of the digestive, 36.54 of the respiratory organs. Thus the main cause of death changes completely. In the first year of life stomach and intestines, in the second bronchi and lungs, are the sources of increase of the death-rate. The respiratory organs are better protected, habitually, in the first year, and the digestive organs more improperly treated. Those infants who survive the first are exposed to the same parental ignorance and carelessness concerning the requirements of the organs of respiration in the second.

Mortality diminishes with every day of advancing life. Every additional hour improves the baby's chances for preservation. Of 1,585 infants born alive, 687 died in the first month, 222 in the second, 157 in the third—1,066 in the first quarter. According to the records of the Grand Duchy of Baden, during the twelve years, 1852–1863, of infants born alive 26.13 per cent. died in the first year; of these 10.60 in the first, 3.06 in the second month. Thus more than one-half of those dead before the end of the first twelvemonth, perished in the first two months. Thus the causes of disease are more active the earlier they are brought to bear upon the young with its defective vitality.

Two grave conclusions are to be drawn from this fact. The first is, that the diminution of early mortality depends on avoiding diseases of the digestive organs by insisting upon normal alimentation. This is principally important in the first few months. While breast-milk has been shown to lower infant mortality through the whole first year, it does so more in the first few months. Thus, though an infant may not be fed on breast-milk through the whole normal period of nursing, a great gain, indeed, is accomplished by insisting on nursing, though for a limited time, perhaps two months only. There are but few mothers but will be capable of nursing during that brief time, and none who ought to be spared the accusation of causing ill-health or death to her baby if she refuses to nurse it at least through the first dangerous months. The second conclusion, resulting from the above figures, is this, that the dietetic problems and rules for the infant concern the digestive organs mainly. Thus their physiology and pathology, as influenced by feeding, will be the main objects of the following pages; and one of the principal difficulties in this connection will be found in the selection of the proper artificial food when breast-milk cannot be obtained.

Breast-milk, when to be given—Loss of Weight.

The question as to whether the newly-born child should be put to the breast at once or after waiting a short time, can perhaps be better approached after we shall have considered certain changes in weight which the child undergoes. The commonly accepted rule, that the weight of the normal child stands in a necessary relation to its condition, may be taken for granted. In speaking of such a relation, however, we exclude the slight losses of weight due to evaporation of the amniotic fluid, the removal of vernix, or the evacuation of already formed meconium and urine. The writer who first distinctly stated the fact that the newly-born child lost in weight after birth was Chaussier. Since then Bouchaud, Haake, Winckel, Gregory, Edlefsen, Ritter, Knopf, Krueger, Kesmarzsky, Ingerslev, and others have followed up the subject with activity. Still another investigator, and one of the most accomplished, is Kehrer. Chaussier went only so far as to observe that children continued to lose in weight from one to five days, when they began to gain. Kesmarzsky found a rapid loss during the first two or three days; after which there was a gradual increase, but so slow was it that by the seventh day scarcely one-half of what was lost had been regained. Haake ascertained that in the first twenty-four hours there was an average loss of four ounces ; according to Winckel it was 3.47 oz. for boys and 4.25 oz. for girls. According to Haake, the total loss of weight amounted in boys to from one-sixteenth to one-seventeenth of the entire weight; in girls it was from one-fifteenth to one-sixteenth. Winckel found that the total loss varied between 3 and

15 oz. (90 and 450 grms). Thirty-three per cent of newly-born children had not recovered their original weight by the ninth day, and it was observed that boys recovered a little more quickly and lost less than girls. With the exception of Breslau and Ingerslev, all observers seem to agree upon this point. There appears, also, to be no difference of opinion with regard to the observation of Winckel and others, that those children who were freely nourished with breast-milk began to increase in weight on the third or fourth day, while those fed upon cow's milk had not regained their original weight by the tenth day.

Of no less interest is the observation, that heavy children suffer less loss than light ones (Ingerslev), and that the children of primiparæ lose more (7.2 per cent.) than those (6.48 per cent.) of multiparæ. According to Ingerslev, the weight of the children (3,450 in the Lying-in Hospital at Copenhagen) increased with each successive pregnancy. Duncan had stated that the age of twenty-nine in the mother marks the maximum point in respect to the weight of the children born. Ingerslev's results uniformly showed that of 50 children raised at the breast, 47 lost in weight until the third day, and 33 did not begin to gain until the fifth day. These facts acquire a greater theoretical and practical significance by comparing them with observations made upon the lower animals (Kehrer). In all mammals there is a loss during the first hour or day, depending upon evaporation of fœtal fluids, or the discharge of meconium and urine. But aside from this, there is in them an immediate, and uninterrupted, though varying, increase in weight. The reason of this lies in the fact that the young of animals—the dog, rabbit, cat, or deer, for example—begin to suck directly after birth, often while yet attached by the umbilical cord. The pig and lamb, too, take the dug after an hour, and the calf and foal five or six hours after birth. This early sucking has a bearing upon the production of the milk. The udders of these animals begin to secrete earlier than the average breast of the human female. Colostrum begins to flow even before the commencement of labor. During parturition the dugs swell, and at birth there is an abundant supply of colostrum ; and the young animal, possessed of no prejudice in respect to the "slight nutritive value" of colostrum, sucks and thrives.

From the foregoing series of facts we draw the following conclusions: Large children—hence, as a rule, boys—suffer less loss of weight and recover more quickly than small ones. A medium age on the part of the mother is favorable to the production of large children. Feeding with cow's milk delays the increase in the child's weight. Putting the child at once to the breast affords a means of increasing the weight immediately.

It will rest with the social science of the future, controlled by liberality and culture, to determine how far measures shall be taken to prevent child-bearing among women who are immature both in body and years, in order to insure the generation of children with larger frames, and hence better adapted to the conditions of life. In this way only could the probability of producing larger children be increased. We have general reasons for believing that our babes are larger than those of former centuries. For we know that, through the improved facilities for obtaining food and the increased protection afforded to life, health, duration of life, size and strength of body, have all been improved and augmented. For, in spite of the tendencies of our civil industries to create at the same time immense fortunes and immense misery, and though we still have with us the "poor peasant boys who have to die before they have had a single chance of once eating a square meal" (Zimmermann, History of the Peasant Wars), yet the life of the average man is better supplied, better protected, more vigorous, and of longer duration than ever before. The justness and moderation of future periods of development, in elevating the general morality, will improve the stamp of the race. But we do not need to wait for the future to arrive at some practical and immediate conclusions.

The more abundant the supply of mother's milk, and the earlier it is furnished, *i. e.*, the sooner the child is put to the breast, the better it will be. With every hour of continued loss of weight, the newly-born child is losing vigor, and muscular power besides. The child often must learn how to suck, and, while it makes its first efforts, the mammary gland is stimulated through reflex action, producing increased congestion and secretion. The loss of weight on the part of the child must not be underestimated. The animals upon which Chaussat experimented had but to lose a fifth of their weight before dying of starvation.

It is true, however, that most women do not have any colostrum in their breasts till some time between the first and fifth days, usually. Vigorous women or delicate women, with well-developed breasts, are indeed the exception. But it happens often enough that even before the birth of the child, a moderate secretion from the breast takes place, and it is not so very rare that the child finds nourishment directly after its birth. These comparatively exceptional cases should become more the rule. The cattle-raiser pays very great attention to feeding during the last few months of pregnancy and during parturition. But the child-bearing woman is treated differently. The domestic animals receive, directly after the birth of their young, quantities of nourishing and easily-digested liquid food. But for centuries it has been the custom to put the puerperal woman upon a starving diet, however much her health may have suffered or her strength have been reduced. The demand for sufficient nourishment should not, however, lead to any excess (A. Flint, Sr., Barker), for even the cattle-raiser knows that too much or too coarse food tends to induce obstruction and fever. But the food, both in quantity and quality, should be sufficient to supply the blood with protein. For the dictates of common sense teach that the puerperal woman should not in nine days lose one-twentieth of her weight. I conclude, therefore, that the diet, both of the pregnant and the puerperal woman, should be such as to favor early secretion of milk, enabling the child to be nursed at an early period and at regular intervals.

Period of Weaning.

The normal time for weaning corresponds with important changes in the digestive apparatus of the infant. It has arrived when a group of two, four, or at most six incisors has made its appearance, viz., about the eighth or tenth month. I look opon this rule as an axiom as long as we have to deal with normal children, though Fleischmann objects to its validity. He relies on the increase of weight as the proper measure of normal development, and requires infants to continue nursing as long as their weight is on the increase. But he forgets that not a few infants grow larger and heavier while and because they are abnormal. Many of them are fat, heavy, rotund, and apparently in good condition; but the trained eye discovers rhachitis as the cause of this rotundity and obesity. Many become more rhachitical with every week of continued nursing; many cases of rhachitis depend on nothing but protracted nursing. Thus, the fact of a child not having teeth at the normal time, though of full or nearly full weight, indicates the necessity of a change of food, that is, weaning. Sometimes that is the only treatment and care required by rhachitis, complicated as it is with retarded protrusion of teeth, late development of osseous and muscular tissue, with constipation, hyperæmia, and perspiration of the head, and occipital baldness. Such infants, when, after changing wet-nurses, or after having been weaned altogether, they begin to become more normal, will lose in weight; and this loss of fat and weight ought to be hailed with joy. In other cases, though the general health of the mother be good, her mammary gland may be developed insufficiently, and its secretion defective. In but very rare cases is it totally absent, but it is sometimes abnormal in quality, and therefore injurious. When this is proved by direct examination, or by its effect on the nursling, it is time to wean or change breast-milk. Where an inheritable disease is discovered in the mother, she has injured her offspring sufficiently before birth. Consumptive, syphilitic, or rhachitical mothers ought not to nurse. A healthy wet-nurse, or even artificial feeding, is preferable to the continuation of a lasting injury. No baby has a good chance at the breast of such a mother; many will thrive even better on carefully regulated artificial food.

Acute puerperal diseases prevent women from nursing, for a continuous fever stops the secretion of milk. Mastitis is apt to terminate nursing very abruptly; thus the preventive care of the nipples and the cure of superficial erosions are of the utmost importance. Chronic diseases of the uterus do not always form a contraindication to nursing; on the contrary, regular and protracted nursing improves insufficient involution. Women who lost babies with acute tuberculosis, and those syphilitic ones, whose babies are not liable to infect wet-nurses because of the absence of specific ulcerations about lips and mouth, must not nurse. Epilepsy and other serious nervous disorders, and chronic exanthemata on the part of the mother, contraindicate nursing, or require early weaning.

So does anæmia, though its effect on the composition of the milk be not always the same. In some specimens all the solid constituents were found diminished—in others all of them, with the single exception of sugar; in others, again, there was less casein and sugar, but more butter (which results from a transformation of casein and sugar).

It is not the above serious disorders of the nervous system only which contraindicate nursing. Less important affections—which, however, attack suddenly—influence milk considerably. Burdach reports the case of a woman who suffered from "nervous attacks;" after each attack the milk was transparent and of varnish consistency for hours. Convulsions have been noticed, also diarrhœa, in babies at the breast of women suffering from violent emotions. Berlyn reports the case of a baby who thus turned pale and was taken with a convulsion and hemiplegia. Levret has even the report of a young dog who contracted a convulsion by taking the breast of a woman after she had been subject to mental emotion. Contesse has the case of an irascible mother who lost ten children; the eleventh thrived perfectly at the breast of a wet-nurse. All such reports are not fabulous, for the effect of the nervous system on secretions is well established, be they lachrymal, salivary, renal, or mammary. Agreeable emotions on the part of the mother are followed by copious secretion of milk; depressing ones diminish, sudden influences suppress it (by contraction of blood-vessels). But not only increase or decrease is observed: there is a chemical change also depending on the change in the amount of water, resulting from vaso-motor disturbances and abnormal cellular action. After a hysterical attack, Vogel found milk transparent like whey, and without the taste of sugar. It contained more water and less solid constituents: water, 908.93; sugar, 34.92; casein, 50.0; butter, 5.14; salts, 1.01, with a specific gravity of 1032.99. Thus the many cases of colic and diarrhœa on the part of the nursling find their ready explanation. It is true that convulsions and sudden deaths offer greater difficulty to a satisfactory explanation. But such cases, though they be rare, are explained by the ready and serious reflex irritability of the infant organism.

Shall a Baby be weaned when the Nursing Mother becomes pregnant again, or when Menstruation is re-established?[1]

Lactation and pregnancy are incompatible. It is but a rare occurrence that a woman has strength and blood in sufficient quantity to sustain herself, a nursling, and an embryo or fœtus, besides. Therefore, as early as 1758, a law was passed in France compelling wet-nurses to inform their employers of the occurrence of another conception. Frequently the uterus will be unable to resist the persistent mammary irritation kept up by nursing, and thus the fœtus is expelled. The milk of pregnant women undergoes a certain number of changes. According to N. Davis, the

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[1] Cf. Jour. Obstet., etc., July, 1877.

solid constituents decrease, particularly fat, salts, and casein, and the milk assumes the nature of colostrum.

The changes brought on by menstruation are analogous, according to the same author, although not so complete. Ch. Marchand examined three specimens of milk, one of six days before menstruation, one during menstruation, and one six days after menstruation.

Six days before Menstruation.

	First individual.	Second individual.	Third individual.
Butter	32.24	28.56	37.24
Milk-sugar	68.25	69.31	69.75
Casein and albumen	20.20	16.75	18.40
Salts	1.90	1.74	1.82
Water	877.41	883.64	872.79

During Menstruation.

Butter	27.45	30.32	33.15
Milk-sugar	65.46	65.15	64.42
Casein and albumen	21.34	17.21	19.10
Salts	1.98	1.80	1.89
Water	883.77	885.52	881.44

Six days after Menstruation.

Butter	29.41	29.24	35.54
Milk-sugar	69.15	68.87	68.95
Casein and albumen	20.90	16.47	16.27
Salts	1.89	1.82	1.72
Water	878.65	883.60	877.42

Thus there is during menstruation a marked diminution of milk-sugar, a trifling diminution of butter, and a trifling increase of albuminous material.

The above results agree with those obtained by Becquerel and Vernois, who found sugar diminished (40.49 : 43.88), and albuminates and extractive material increased in quantity (47.69 : 38.69). They assert that infants nursed by menstruating women experience no injurious effects.

In general milk-sugar and albuminous contents appear to keep up a somewhat inverse proportion; while the latter are increased, the former diminishes in quantity.

Besides, from a few observations made, it appears that milk-sugar is always found lessened during the continuance of a uterine affection, be it hemorrhage or catarrh of the uterus or vagina.

In addition, there are certainly differences in the condition of the milk, which can be appreciated or estimated, particularly as to the size of the corpuscles. The milk corpuscles—all of them spherical, refracting light, and enclosed in a membrane consisting of insoluble albuminates—range from 1.25 to 4. mm. in diameter. Fleischmann divides them into three classes, large, middle-size, and punctiform. The first he found in old women, in protracted lactation, in fevers, and during menstruation.

But still opinions differ as to whether menstruation contraindicates nursing or not. For it is true that there are many observations of colic, vomiting, and acid diarrhœa on the part of the nursling, but just as many of entire comfort during the menstruation of wet-nurse or mother. It is customary, when menstruation makes its reappearance, either to wean or to change wet-nurses. But in very many cases nursing is persisted in for the purpose of preventing both menstruation and pregnancy. For the functions of the mammary glands, on the one hand, and those of the ovaries and uterus, on the other, were often considered to exclude each other. Such an exclusion, however, does not exist. Pregnancy may occur without menstruation, no matter whether lactation is going on or not. I had a patient who never had a child during her married life, for a number of years. When she applied to me she had not menstruated for ten months. Not a drop of blood had been seen. Her uterus appeared rather too large for a normal condition ; the uterine sound, introduced for diagnostic purposes, destroyed a normal and fresh two months' fœtus. Nor is this the only case of pregnancy commencing during amenorrhœa. Cases will be met with occasionally in the journals, and would be so more frequently if practitioners were as anxious to instruct their professional brethren by the mistakes they made as to benefit them by the reports of their successes. During lactation pregnancy is not infrequent, no matter whether menstruation is regular, has reappeared, or has disappeared again. Meanwhile the secretion of milk may be quite copious, and exhibit no very apparent alterations.

In general, lactation is persisted in, and is dispensed with at the expiration of nine or twelve months. At this time menstruation has usually reappeared and is regular. That length of time is also required to fully re-establish the uterus and ovaries without regard to lactation. The advice of the English author, who wanted women to nurse their babies through a period of four years, is therefore but poorly sustained by reasons. His were three. The first was, that the babies were thus fed both well and cheaply ; but that mode of feeding would, indeed, be neither good, nor cheap, nor sufficient. His second reason was, that the woman would escape a renewed pregnancy and the domestic misery emanating from the abundance of not-wished-for children—which is contrary to the established facts. Thirdly, he urged that procedure for the purpose of preventing over-population. But the real result would be to check over-population by destroying the women through exhaustion and abortion. Schœpf-Merei, however, knew of a case of that kind, where the woman would have swelled the heart of that style of Malthusian with joy and satisfaction. Her twenty-two pregnancies resulted in the existence of one child.

Some time ago Roberton remarked that one-half of the nursing working-women of Manchester, Eng., conceived during lactation; and but a few years ago L. Mayer collected facts concerning the frequency of menstruation during that period. He tabulates 1,285 cases in 395 individuals. Of 1,285 there were 685 who nursed. Of these 685 there were 402 who menstruated after some time. The first menstruation appeared after six weeks in 99 (25 per cent.), after twelve weeks in 46, after four months in 41, of the above number.[1] Menstruation, in his observations, had no injurious influence upon the health of the nurslings. Therefore, the reappearance of menstruation, in his opinion, is no indication for either weaning the baby or changing the wet-nurse. There is but one such indication, viz., *ill-health of the baby*, brought on by the continuation of nursing. For the diminution of the quantity of blood in the maternal organism, or the thorough change in its circulation, *may*, but does not necessarily, result in either quantitative or qualitative alterations of breast-milk. In cases of doubt, the regular use of the scales may decide the question of nursing or weaning by determining the weight of the baby.

The effect of physiological or pathological changes in the nursing-woman on her mammary secretion can, after all, not be counted up, or defined, with mathematical certainty. The latter is rendered impossible by the variability of vital processes, and the changes taking place in the living subject. Still there are on record a number of good observations which illustrate the effect of chemical substances or of diseases on the breast-milk of either animal or woman. A number of them are very useful in determining the changes taking place in the condition of the milk, and the influence it may have on the baby, or the manner in which it necessitates weaning, either total or partial.

Coloring materials are known to enter into and pervade all sorts of tissues, even bones. Milk turns yellow by the eating of caltha palustris, saffron, and rhubarb, according to Mosler; red by rhubarb, opuntia, rubia tinctorum; blue by myosotis palustris, polygonum, anchusa, equisetum, according to Schauenstein and Späth. Still the blue color, which penetrates the milk uniformly, must not be mistaken for the superficial layer of discoloration observed in milk after a few days' keeping. The latter is of parasitic character (different though from the lactic acid parasite of Hessling), and identical with penicillium glaucum and aniline blue. It extends into the lower layers but gradually, infects, by communication, normal milk, and remains unchanged, though the milk be filtered through threefold paper. When introduced into the stomach, the milk thus parasitically infected, is apt to give rise to acute gastritis and enteritis.

Ethereal oils are very apt to enter the milk. But to prove their presence otherwise than by taste or smell is not always easy. For organic

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[1] Tilt obtained from his experience the following results: Of 100 women whose menstruation returned during lactation, 45 retained their milk unchanged both in quantity and quality. In 8 the quantity diminished, 1 lost her milk altogether, 24 had a large flow during, and 15 after, menstruation. In 5 the percentage of solid constituents decreased.

chemistry has not even advanced sufficiently to decide whether quinia, which, when given internally, communicates a bitter taste to the milk, is eliminated as quinia or in some other form (Chevallier and Henry). Nor can alcohol, opium, or morphia be discovered with absolute certainty. Still the occurrence of poisoning through milk is an undoubted fact. An endemic is reported, in Italian and German journals, of an affection from which many people suffered, in the neighborhood of Rome, Italy. The symptoms consisted of vomiting, diarrhœa, intense thirst, and diminution of temperature and pulse. The milk of the goats was suspected; the goats were, however, declared to be in good health by the veterinary surgeon, and on analysis the milk was found free from organic poison of any kind. Attention was then drawn to the food of the goats. On the pasture grounds there were found large quantities of clematis vitalba, conium maculatum, colchicum autumnale, plumbago Europæa. Again, the milk, and the masses brought up by vomiting, were examined and found to contain colchicine. An English infant, two days old, died soon after taking the mother's breast for the first time. The coroner of Manchester investigated the case, and elicited the fact that the mother was an habitual opium-eater, the amount of the poison swallowed weekly being about an ounce. Dr. Fletcher's testimony went to show that the symptoms with which the infant died were the effects of opium.[1]

More positive results have been obtained by inorganic chemistry; a number of substances have been found in the secretion of the mammæ. As far as human milk is concerned, these results are, however, mostly obtained by induction or clinical observations, for very few attempts at a direct chemical examination have been made. Large quantities of milk are required for examination, as a rule; and, therefore, goats, sometimes cows, have been used for experiments. Iron is contained in milk, normally: in the ashes of human milk, according to Wilderstein, phosphate of iron 0.21 per cent., somewhat less than in the milk of pigs and cows. It was not, however, found by Harnier and Simon. Other experimenters—Lewald, Marchand, Chevallier and Henry, Rombeau and Roseleur—found soluble salts of iron, when given internally, within a short time in the milk; but they soon disappeared. Bistrow noticed a rapid improvement in the general condition of infants, when the wet-nurses took iron; this, however, is no direct proof, in itself, of the mammary elimination of iron, inasmuch as the general improvement of the health of the wet-nurse would explain a better composition of her milk and the thriving of the nursling. Wilderstein's experiments with iron administered to goats had the result of diminishing the quantity of the milk, but its specific gravity increased and the ashes contained twice the normal amount of iron. This effect was not observed, however, before twenty-four hours had elapsed.

Bismuth, when administered, was found in the milk by Lewald, Chevallier and Henry, and Marchand; by the first in small, by the second in greater quantities, by the last after a very short time.

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[1] Med. Press and Cir., 1878.

Iodide of potassium was experimented with by Lewald. When fifteen grammes were given, its presence was detected after four days. Then twenty-one more were given. The effect was kept up by that dose, and did not disappear before seventy-two more hours had passed by. When, after that, iodide of potassium was given, the milk exhibited iodine after four days, and continued to do so for eleven days. Supported by such facts as these, Leviseur (Jahrb. f. Kinderheilk., N. F., VI., 3, 1873) recommends to treat the wet-nurse with iodide of potassium for syphilis, sulphate of quinia for intermittent neuroses, arsenic for cutaneous secretions in the infant.

Arsenic was found in the milk after seventeen hours. It persisted in passing through the mamma sixty hours.[1]

Lead and oxide of zinc, probably all other preparations of zinc, pass into the milk. Oxide of zinc was found in from four to eighteen hours after the administration of a single dose of one gramme; it disappeared in from fifty to sixty.

Antimony passes into the mamma very easily, and requires caution.

Mercury was not found in the milk by Peligot, Chevallier, Henry, and Harnier. Lewald and Personne proved its presence. O. Kahler examined, by Schneider's electrolytico-chemical method, the milk of three women under treatment with mercurial inunctions, but found no mercury. Thus the treatment of infants affected with hereditary syphilis through the milk of their wet-nurse is not yet proved rational. My own clinical observations do not favor the plan at all. The internal administration of mercurials, when persisted in sufficiently, yields very satisfactory results in the usual form of hereditary syphilis, which exhibits its first symptoms between the fifth and ninth weeks. Even the formidable species of syphilis, attended with pemphigus in the newly-born, may be controlled by subcutaneous injections of the bichloride—care being taken that the solution administered is weaker than that recommended by Lewin.

Carbonate and bicarbonate of potassa and the sulphates of soda and magnesia pass out through the milk. The vegetable acids of alkaline salts reappear as carbonic acid. Sulphides of alkalies have not been found by Marchand.

Thus there is any number of opinions and results of researches. Is it that chemistry is so uncertain in its methods of examination, or the reputation of the men who vouch for their results with their names so little reliable, or is the material on which the experiments were made variable in its composition or perhaps not quite well known in its physiological constituents?

We shall see that the fault lies very probably in the material on which experimenters tried their skill.

The nature of the albuminates of the milk is by no means settled. Hoppe believes that he proved the existence in the milk of an albuminous

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[1] Hertwig asserts that arsenic given to a cow for medical purposes in medicinal doses may poison her meat.

substance identical with the albumen of the blood serum. There is, according to him, but one difference between casein and the albuminate, viz.: that the former, when treated with caustic potassa, yields sulphide of potassium, a change which does not take place in the latter. The albuminate undergoes its transformation into casein by a fermenting process, produced by lactic acid according to Zahn, by a hypothetical ferment according to Kemmerich.

Thus seemingly simple questions cannot yet be answered with absolute certainty. It cannot yet be stated that, or that not, the albumen of the serum of the blood is found in the milk. Still, the conditions of things vary. The walls of the blood-vessels of the mamma are thinner or thicker, more or less permeable, and vaso-motor influences will change circulation and nutrition. Thus there may be cases in which blood serum is simply added—as a transudation—to the secretion of the mammary gland. In other secretions too we meet with considerable differences, many times without any surprise. By assuming that blood serum is found admixed with milk, we can much better explain the cases of infants influenced by medicines, infections, emotions acting through the milk, than when we look upon milk simply as the result of transformed glandular substances.

For such it is normally. The mammary gland is no filter, through which the serum of the blood, or the solutions of salts, or the transformed foods are rendered accessible to the hungry young. The quality and quantity of milk depend upon the development of the gland. Milk is not the product of the action of the cells; it is the transformed cells, the very organ. Thus the nursling is the veriest carnivorous animal. As long as the epithelium has not undergone a total change, the secretion is not milk, but colostrum, with its large globules. The character of the gland influences the milk, much more than food. The latter influences milk only by building up the gland, the cells of which receive materials of different kinds, the principal of which is albumen. Where too large an amount of nitrogenous material is received, compared with carbohydrates, the proportion of albumen destroyed is too large, and the result may be that both the gland and the production of milk decrease. Therefore, the proportion of nitrogen in the food ought not to be disturbed beyond the increased necessity of the secretion. A moderate amount of albuminous substances suffices for the nursing woman and the nursling both, and for both the fixed and the circulating albumen. The amount of the latter is particularly influenced by the use of water. Thus the favorable influence on the amount and character of the milk, of all sorts of beverages, is easily understood.

The character of the milk is beautifully illustrated by its chemical composition. Its ashes are tissue ashes, not those of plasma, for they contain much potassa and phosphate of lime, but little chloride of sodium.

The question whether medicinal agents will appear in the milk is not, therefore, sufficiently well defined, and cannot be answered either affirmatively or negatively as long as the milk is not of a stable quality. Milk secreted from an insufficient mamma, by a woman not in full health and vigor, by an old woman, by a very young woman, by an anæmic woman, by a convalescent woman who has used up a large portion of her albumen both in circulation and in the tissues, by a woman soon after confinement, by a neurotic woman with frequent vaso-motor disturbances—milk, in fact, which is not mainly composed of mammary epithelium, and contains admixtures, small or large, of transuded serum, is apt to be impregnated with foreign elements circulating in the blood. The indications on the one hand for permission to nurse, on the other for the administration of medicines to a nursing woman, must therefore be defined with a greater strictness than is usually the case, and will have to be modified, if the greatest good is to come from nursing to the young infant. The good results obtained in many cases by artificial feeding, in preference to nursing, are, therefore, more than accidental.

The milk, then, is under normal circumstances, and always ought to be, a secretion from the cells, not a transudation from the blood.

The difficulty of influencing the mammary secretion is, however, not equally great under all circumstances. In the first period of lactation the glandular transformation is not yet accomplished. The secretion is of a different nature. It requires days to exhibit casein. Until then the protein shows the nature of albumen. At the same time the percentage of butter and salts is very high indeed, both of which explain the laxative character of colostrum. No less do macroscopic and microscopic observation convey the impression of its being incomplete. It is yellowish, thickish, the fat globules are large, unequal, sticky, and mixed with epithelium almost unchanged. There is less potassa and more soda than in normal milk, approximating it to the chemical character of plasma. Besides, colostrum of the cow has not unfrequently been found to contain blood and to coagulate when being boiled. Thus colostrum[1] is more like a transudation than a glandular secretion. Such colostrum, as stated above, is frequently found with disturbances in the general health, in anæmia, fevers, pregnancy, or advanced age of mother or nurse. Its administration must result in disturbing the health of the nursling, and therefore the greatest attention should be given to this matter, inasmuch

	Four weeks before part.	Nine days before part.	One day after part.	Two days after part.
Water	945.24	858.55	842.90	867.88
Solids	54.76	141.45	157.10	132.12
Albumen	29.81	80.73	......	......
Casein	......	......	......	21.82
Butter	7.07	23.47	......	48.63
Milk-sugar	17.27	36.37	......	60.99
Salts	4.41	5.45	5.12	3.10

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[1] Clemm's Analysis of Colostrum.

as transudation may be mixed, at almost any time and in almost any proportion, with the normal mammary secretion.

This, then, has no normal standard, neither chemically nor physiologically. That a mere transudation should contain all sorts of material circulating in the blood-plasma is evident. Therefore colostrum is apt to transfer to the nursling the liquid constituents of the mother's blood, no matter whether normal or abnormal, beneficial or injurious, organic or inorganic. The reports of infants harmed by the mother's opiate, influenced by her taking mercury, belong, therefore, mostly to the earliest period of lactation, or to a period of sickness, or debility on the part of the woman. The more nearly normal the mammary secretion the less the danger in this respect. Very few persons, however, are ever in undisturbed health.

Another point still is worthy of remark. Chemical investigations have been made almost exclusively on the breast-milk of animals. Their results are sufficiently various indeed, and still this material is so much more stable than the milk of woman, influenced as she is by wealth or poverty, idleness or work, rest or worry, emotions and thoughts, health and sickness.

Selection of the Wet-nurse.

In choosing a wet-nurse we should, of course, see that she has "good" milk and a plenty of it. The obstetricians vie with each other in naming with great minuteness the qualities which a good nurse should possess. Manifestly a nurse with mastitis, sore nipples, or acute puerperal disease, should not be employed. Such conditions would be an objection to the mother's nursing her own child. The nipple of the breast should be so formed that the child can lay hold of it. Whatever be the extent of "the highly vascular surface covered with secretory epithelium" (as the mammary gland was lately described by Boll), if the nipple be too small a weakly child cannot seize it, nor can a strong child if it be depressed. The nipple should rather be too large than too small; rarely is it so large that the child is unable to take it into its mouth. It should be well developed in every respect and prominent. The breast itself should be to the touch rather hard, corded, and elastic—not soft and flabby. The skin should be thin and transparent, with the veins plainly showing through. By slowly stroking it in the direction of the nipple, or by moderat epressure, the milk should flow out in a stream. If the breast has not been emptied for some time the first milk that appears is watery and bluish, and, on the other hand, just after the breast has been sucked the milk is whitish. Under certain circumstances it may be of practical importance, in selecting a nurse for a feeble child, to choose a multipara; her milk will flow more freely, and the chances are that she will know better how to tend the child than would a primipara. Generally speaking, the age from twenty to thirty years is to be preferred. The nurse's child should be of about the same age as that of the foster-child.

The constituents of the milk vary with the period of lactation, as will be seen from the following table of Vernois and Becquerel:

	First month.	Second month.	Third month.	Fourth month.	Fifth month.	Sixth month.	Seventh month.	Eighth month.	Ninth month.	Tenth month.	Eleventh month.	Twelfth month.	Thirteenth to eighteenth month.	Nineteenth to twenty-fourth month.
Specific grav.	1031.69	1033.11	1032.70	1032.90	1032.10	1035.35	1034.97	1031.37	1032.88	1031.44	1031.61	1030.68	1032.50	1030.81
Water......	872.84	872.99	886.16	889.67	888.25	901.51	891.35	889.49	891.65	889.28	900.63	889.04	891.34	876.55
Solid ingre'ts.	127.16	127.01	113.84	110.33	111.75	98.49	108.65	110.51	108.35	110.72	99.37	110.96	108.66	123.45
Sugar.......	40.40	43.13	43.37	44.47	44.66	42.00	44.81	41.52	45.31	45.84	47.62	43.91	45.92	41.33
Butter......	39.55	34.05	31.22	27.79	27.31	16.57	24.35	22.79	23.06	25.03	19.47	24.61	24.44	43.47
Casein......	45.38	48.26	37.92	36.96	38.28	38.63	38.86	45.02	38.79	38.57	31.06	41.06	36.98	37.32
Salts........	1.83	1.57	1.33	1.1	1.50	1.29	1.26	1.18	1.19	1.28	1.22	1.38	1.32	1.33

Hence the casein increases to the end of the seventh month. A temporary increase takes place in the eighth and twelfth months. The butter decreases from month to month with slight variations, beginning from the fourth month. The sugar steadily increases and reaches its highest point in the eleventh month.

Still the nurse's milk will not always suit the foster-child, even though the age corresponds, and occasionally another nurse's milk at a period of lactation not corresponding to the child's age will answer better. The above tabulated figures are simply averages, and imply no invariable law of nature. Not unfrequently the physician will prefer a wet-nurse whose child is a little older than the child she is employed to nurse. He will always be cautious about choosing one just delivered. The possibility of the nurse or her breasts becoming subsequently diseased, or of the non-appearance of the milk secretion, must be taken into consideration. So the rule is, whether the ages of the two children differ by a few months or not, that bluish milk, with abundance of sugar, should be chosen for younger children, and for older ones milk richer in casein and butter. In this connection it may be observed that by testing the milk itself, even though only superficially, we obtain a better estimate of its character than by any other standard (such as that adopted by L. Héritier, who claims to have discovered a marked difference between the milk of blondes and that of brunettes[1]). The best criterion for the milk is the appearance of the nurse's child—if it be still living.

Wet-nurses, whose children are dead, should be examined with particular circumspection. The cause of death should be ascertained; whether it was a constitutional disease, or an intestinal catarrh—the result possibly of an excess of casein, or of salts, or of sugar, in the milk. Generally, even though the child may have been dead but a few days, the milk secretion will have notably diminished or have already begun to dry up. For rarely does the common practice of sucking, pumping, or milking the breasts out, for the purpose of temporarily keeping up the secretion till the nurse finds a place, accomplish its object. I have often seen the breasts dry up entirely under these circumstances. In such a case, obviously, much less will be accomplished by examination with the microscope or galactoscope than in the average of cases.

Inquiry into the general condition of the nurse should of course not be neglected. It should be undertaken in the same way as we would examine the *status præsens* of a patient. Whether we should be so precise as to count the number of teeth, or particularly note the shade of hair, may be left to the taste or zeal of the practitioner. The nurse's digestion is generally good, and her appetite leaves nothing to be desired. Particular

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	Milk of blondes.	Milk of brunettes.
Water	892	853.3
Butter	35.5	54.8
Casein	10	16.2
Milk-sugar	58.5	71.2
Salts	4	4.5

attention is of course to be directed to constitutional diseases, and especially to syphilis. But, after all, it is clearly impossible in any particular case to undertake to guarantee that the quantity and quality of the milk will, under all circumstances, remain satisfactory. Both will depend upon the general condition of the nurse and partly upon the care she receives.

Diet of the Nurse.

To the question as to how the nurse's food shall be regulated in a manner consistent with what has heretofore been said, our answer can only be given in very general terms. Strong salts, under all circumstances, are to be avoided; hence saline cathartics, and the immoderate use of common salt, as well as the use also of the ethereal oils and strong spices. Further to be avoided are all those things which may retard or derange digestion and assimilation. Generally the nurse regards her place as a land flowing with milk and honey, where the birds already roasted fly into her mouth—her "Canaan" and her "Eldorado" together—and she continues to gorge herself long after the appetite has ceased. A diet that is a little more albuminous than usual is indicated; but if it contains too much albumen, or is exclusively albuminous, it will be unfavorable to the general health as well as to the secretion of milk. The latter is promoted by free ingestion of fluids. The moderate use of beer is often advantageous as a stomachic. Oatmeal gruel, barley-water, and milk have a twofold effect, depending upon the water they contain and upon their nutritious ingredients. Tea is useful chiefly for the water it contains. Potatoes in large quantities or other carbo-hydrates should not be used as chief articles of food. A moderate quantity of fat may be permitted. It is a good general rule that the diet upon which the nurse has flourished hitherto, if a certain quantity of albuminous food be added to it, together with an abundant supply of fluids, makes the best milk and the largest quantity, provided, though, that her mode of life be similar to what it has been heretofore. A nurse taken from the hayfield or the kitchen and shut up in a lady's boudoir for fear lest she might eat an unripe apple, drink a glass of beer, or meet her sweetheart, were she allowed to go out, will not remain in good condition nor give good milk.

According to these principles must we judge of the value of certain articles of food or beverages which have been lauded as milk-producing agents. Among these are beer, butter-milk, milk, chocolate, broths, leguminous vegetables, oysters, crabs, conger-eel soup, etc. But should none of these dietetic remedies prove of any avail, we next resort, with more or less reason and with more or less confidence, to the therapeutic measures which tend to promote the secretion of the milk. C. Gerner, in his chapter (p. 45), *De his quæ lactis ubertatem faciunt*, has collected all of the customary remedies in use in his own and even in Galen's time. Rosenstein recommended a remedy; Hufeland, a milk-powder; Moleschott, the chestnut; Routh, the leaves and stalks of the *ricinus communis;* Gillilan, the *extr. fol. ricini;* and in England and America the external application of the ricinus-leaves gained a short-lived popularity. The list of galactagogues, which Routh presents, makes quite a formidable appearance. I cannot, however, from any success of my own with these remedies, or from that of others, say much in their praise. I have often employed the induced current of electricity to increase the milk secretion, and I believe with good effect. Inasmuch as the benefit derived from electricity in these cases is owing to the increased activity of the circulation, we might anticipate even better effects from the galvanic current.

Substitution of Animals' Milk for the Mother's Milk.

If the mother is unable to suckle her child and a wet-nurse is not to be had, what shall be done? The child should have some kind of food as nearly homogeneous with the breast-milk as possible. In this connection we must take into consideration the chemical composition of the different kinds of milk, together with the practicability of obtaining them. The following tables show the mean composition of human milk (from 184 analyses), and of cow's milk (from 128 analyses), as given by N. Gerber:

	Woman's milk.	Cow's milk.
Water	87.57	86.23
Casein and albumen	1.95	3.70
Sugar	6.64	4.93
Butter	3.59	4.51
Salts	0.22	0.61

According to Moleschott, the proportions of the several ingredients of various kinds of milk in 1,000 parts are as follows;

	Woman's.	Cow's.	Goat's.	Sheep's.	Ass's.	Mare's.
Water	889.08	857.05	863.58	839.89	910.24	828.37
Solid ingredients	110.92	142.95	136.42	160.11	89.76	171.63
Casein	39.24	48.28	33.60	53.42	20.18	16.41
Albumen	......	5.76	12.99			
Butter	26.66	43.05	43.57	58.90	12.56	68.72
Sugar	43.64	40.37	40.04	40.98	57.02	86.50
Salts	1.38	5.48	6.22	6.81		0.29

Of these, with rare exceptions, only cow's and goat's milk are ever employed. The former especially has come into very general use as infant's food, on account of its being so easily procured. How should it be used? Should it be boiled or not? Should it be diluted, and, if so, with what? Or are there certain ingredients in cow's milk which are especially useful and desirable, while others are to be avoided or modified? Can anything be added to the milk which will increase its nutrient effect or tend to curtail its objectionable properties? Finally, is there anything that can be substituted for milk either wholly or partially? All of these questions will in turn demand our attention.

Milk from one Cow.

Is it better for the infant that it should have milk always from one and the same cow? This question cannot be answered for all cases alike. The milk of a pasture cow is certainly preferable to the mixed milk of a dairy where the cows are stall-fed, and to the milk that is sold in shops. Milk kept in a stationary receptacle is not always uniform. The upper layer, after standing for some time, contains more cream than the lower. But the milk of a cow kept by poor people and fed in a stall is certainly no better than the mixed milk which is found in a dairy and is sold in the neighboring town. Furthermore, every cow has its individual peculiarities in health and disease, the same as a woman. I have always preferred to rely upon the mixed milk from a dairy than upon the yield of a single cow. Unlooked-for changes in the cow's health or in the constitution of her milk are liable at any time to produce unpleasant effects upon the child which is fed with her milk, not to speak of any such grave disorder as the murrain.

Condensed Milk.

The method of preparing condensed milk with the admixture of such great quantities of sugar as to yield from 39 to 48 per cent. of sugar in its solid ingredients is a well-known process. With regard to this preparation, Kehrer says that when sufficiently diluted it readily induces the formation of lactic acid, and that delicate children will not thrive on it. In such cases he deems it necessary to add barley-water or oatmeal gruel as well as antacids. Fleischmann also accuses it of causing a predisposition to thrush and diarrhœa. He lays stress upon the fact that even when it has been properly diluted the proportion of the protein compounds to the carbohydrates is diminished, and thereby its nutritive value impaired. My own experience with condensed milk, which has been rather extensive, has led me to learn that when diluted simply with water, even though to the proper degree, it is apt to be followed by disagreeable results; although the influence of the large amount of sugar does not operate in the manner as above alleged. For the sugar which is added to condensed milk is not the easily decomposed milk-sugar. Yet catarrh of the stomach and bowels is a frequent result of its use. I have seen few children enjoy undisturbed health who were fed exclusively upon condensed milk. Those, however, who take it mixed with a certain proportion of barley-water, either regularly, as I recommend, or in cases of temporary necessity, as advised by Kehrer, thrive quite well. I cannot say that I have been able to discover any material difference, whether condensed milk, or good ordinary city milk, was given in this way. But it should not be forgotten that barley-water is a more desirable addition to the mixture than oatmeal gruel, because of the laxative effect which the latter may have. If the condensed milk be given in this way, we need not fear a repetition of Daly's experiences. He found that children took the condensed milk readily, and grew fat; but in case they fell sick they showed but slight endurance; they began to walk late; their fontanelles were slow in closing, and other signs of rhachitis showed themselves.

Boiled Milk.

It is known by experience that the effect of boiling the milk is to check its tendency to become sour, and to abstract a portion of its cream (casein and fat). It is true that the amount thus withdrawn is but trifling; but to rely on spontaneous separation of the cream—which then could be removed—is dangerous, because while cream is forming on the surface the whole of the milk is turning sour. With regard to the diminution of the tendency to become sour, the influence of boiling the milk may operate in various ways. Certainly, amphoteric milk becomes alkaline by boiling. By this means, also, a large quantity of gas (three per cent., according to Hoppe, consisting of $CO^{2}55,15$–$N40,56$–$O4,29$) is expelled from perfectly fresh milk; and the loss of oxygen in that way tends to diminish the formation of lactic fluid. This escape of gas, together with the slight alteration in taste, is doubtless the foundation of the religious aversion with which boiling the milk is regarded in many quarters: "It destroys a certain volatile principle, of unknown nature to be sure, but which unquestionably is beneficial in its effect."[1]

For the reasons given above, I believe that the effect of boiling the milk is beneficial. The abstraction of gas certainly contributes to protect the milk from such influences as those described by Lawson Tait. He found that milk left in open vessels took the odor of substances in its vicinity. Should fungi be present, boiling would either destroy them or at least temporarily prevent their development. Béchamp claims to have found alcohol and acetic acid in the mammary gland itself. Von Hessling has published observations concerning the development of mould in milk, which are interesting as showing that the milk could be so permeated with the germs as to communicate their poisonous nature to the coffee to which it was added; those taking coffee without milk were not affected. Falger considered it necessary, in order to obtain milk as free from vegetable germs as possible, to have it milked directly into bottles that could be tightly corked immediately afterward, and even recommended a special apparatus for antiseptic milking and for preserving the milk hermetically sealed. In addition, but lately, cases of typhoid fever, and infectious diseases in general, have been reported as the results of diseased milk. If all this is anything more than accident or caprice, we may be thankful that in the simple procedure of boiling, we have the means of rendering

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[1] Barret, p. 46. Routh.

the milk safer and more digestible. Under all circumstances I forbid that infants shall be fed on raw milk. A portion of the fat and casein can and should be dispensed with, the formation of lactic acid postponed or prevented, and disease germs destroyed.

Goat's Milk.

The disparity in the results obtained by chemical examinations of goat's milk, and in the methods even of examination, is fully in keeping with the diversity in the clinical results. The fact that goat's milk is generally so easily procured has favored the accumulation of clinical investigations concerning its use. Were the advantages of goat's milk as real as by many observers they are believed to be, surely public opinion would long ago have declared in its favor. People have gone so far as to let the children suck directly from the goat; such extravagance has not been reached yet with regard to cow's milk. My own experience is not favorable to goat's milk. The extreme richness in fat renders it indigestible, and the offensive odor is often objectionable. It is now a long time since I have seen children fed with it. Hauner's experience with regard to goats as wet-nurses is likewise unfavorable. Infants never thrived on the milk. Two remained weak and thin; the others did not retain it; they vomited and had diarrhœa, and were obliged to have other nourishment. The writers on the subject do not agree even as to the chemical and physical constitution of the solid ingredients of the milk. Kehrer having asserted that goat's milk was affected by the artificial gastric juice, the same as cow's milk—an assertion that I have myself very often verified clinically—it was disputed by Kraus, who thought that the coagula which form from goat's milk under the action of rennet, with hydrochloric acid, were much more like the caseine of woman's milk than like that of cow's milk.

After all, as the only animal milks which can be substituted for woman's milk, when this is wanting, are goat's or cow's milk—ass's or mare's milk being out of the question, because of their scarcity—the latter requires further consideration as to its capability of serving as an available substitute for human milk.

Cow's Milk and Woman's Milk Compared.

The differences between the two are unexpectedly great. Human milk is alkaline; the reaction of cow's milk appears doubtful at every moment. At all events, authors do not express uniform opinions. D'Arcet and Petit found cow's milk, when the animal was fed in the stable, always acid; in pasture, always alkaline. According to some, as Bruno Kerl and F. Stohmann, the milk begins to turn acid in the udder. So believes Zahn, who explains the formation of casein out of the albumen of the milk by the incipient formation of lactic acid in the udder.

Hennig succeeded in obtaining alkaline milk by proper feeding. The question is perhaps best answered by observations of Soxhlet and Heintz, who first discovered the so-called amphoteric reaction, which depends upon the relative amount of bi-phosphate of potassa and the two-thirds phosphate of potassa, which is a common constituent in the milk. The former has the quality of coagulating casein. Where it preponderates, milk coagulates more easily, and has an acid reaction. If it is warmed again, it becomes alkaline. The point of practical importance lies, therefore, in the fact that cow's milk is frequently slightly acid ; milk taken from cows fed in the stable being always so. This is one reason why it becomes so frequently necessary to use antacids in feeding children.

The second difference between the two milks relates to the percentage of sugar. There is *more sugar* in human milk, with less casein and butter. Hence its bluish color, and part of the purgative effect of colostrum. Its percentage is particularly high in the milk of anæmic women. When, as frequently occurs, the solid constituents are diminished, diarrhœa is a frequent result.

The transformation of milk-sugar into lactic acid takes place very rapidly, and explains why cow's milk turns acid within a short time. This change does not take place in cane-sugar, at least not to the same extent. For that very reason, cane-sugar is used for the purpose of preserving milk. It is through it that condensed milk remains unaffected for some time. For this reason it is not at all indifferent whether milk-sugar or cane-sugar is added in artificial feeding. It has been said that milk-sugar is preferable; *first*, because it is a natural constituent of natural milk; and, *second*, because it contains phosphates. But it is a fact of much greater importance that milk-sugar turns to lactic acid in a very short time; that thus an excess of acid accumulates in the stomach; that through it protein coagulates and is rendered indigestible, and that it *loosens* alkalies and lime from its phosphoric combination, thereby eliminating phosphoric acid before the proper time, and gives rise to diarrhœa and rhachitis.

This should be a sufficient reason why milk-sugar, as an addition to that which is found in cow's milk, *should be carefully avoided*, and should be replaced by cane-sugar.

The third difference is that there is less butter in the milk of the woman than in that of the cow. The immediate conclusion that may be drawn from this fact is that cow's milk should be deprived of some of its fat, and none, as some have it, added to it.

I know that the probable reason for their recommendation was the attempt at restoring the equilibrium between the fat and casein; but the increase of butter is a dangerous procedure. Even in human milk it is a constituent of doubtful value.

Fat is digested by the pancreas. It is decomposed into glycerine and fat acids. The glycerine combines with phosphoric acid to make glycero-phosphoric acid. The fat acids are saponified with alkalies found in the intestinal tract.

The pancreas, however, acts only when the contents of the intestine are alkaline, or nearly so. This alkaline condition is the result of the presence of the phosphate of soda. Where there is acid in the intestines, the effect of the pancreas is set at naught; or, at all events, lime is washed out, and the formation of bones is retarded. Not only do the bones suffer, however, but also the blood and muscles are wanting in lime and phosphoric acid.

This condition, known by the general name of rhachitis, is then the result, either of original absence of phosphates in the food, or still more frequently of excessive formation of acid in the intestinal tract. Thus it is that rhachitis is so frequent a result of chronic digestive disorders.[1]

The latter, however, is much more frequent than the former; for there are very few infant foods which do not contain a sufficient amount of phosphates for the wants of the organism. In a very young child the contents of the intestinal tract, however, are seldom so alkaline as they should be for normal pancreatic digestion. In fact, normal fæces are very apt to be acid. There is always some acetic, stearic, butyric, capric, capronic, and caprylic acid contained in them.

Hoppe-Seyler found free acids in the fæces of dogs and adults.

Wegscheider met with them in nurslings who received nothing but mother's milk. Their percentage depends very probably upon two causes —either the quantity of food introduced into the stomach is too large, or the quantity of digestive fluid is too small. From what we know from direct experiments upon the diastatic effect of the pancreas in small children, we are entitled to conclude that the function by which it digests fat is limited at that as at any other age. This is not only a conclusion justified *à priori*, but direct investigations of Wegscheider led him to the following important results : *fats are not completely absorbed; one part*

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[1] The question, if by the introduction, into the digestive organs of an animal, of lactic acid, the bones can be deprived of lime, is certainly an important one. When lactic acid is introduced into the system, or when it is formed by the normal, or, more frequently, by an abnormal, process of digestion, can it influence the osseous system? E. Heiss (Z. f. Biol., XII.) reports the following experiment: A dog, one and a half years old, and weighing 4,701 grms., was fed through 308 days on 44,983 grms. of meat, 5,961 of pork, and 2,286 of lactic acid. When he was killed, he weighed 4,076 grms. Meanwhile, the amount of lime and magnesia contained in his urine and fæces amounted to just the sum introduced ; thus certainly lactic acid eliminated no lime or magnesia. The relative weights of the organs, secretions, and blood were not changed. There was no anomaly of the bones, particularly no rhachitis or osteomalacia.

We have to conclude, then, that, as but little lactic acid was eliminated, the latter is decomposed in the system. But, on the other hand, is it not possible that lactic acid, slowly and irregularly formed, should act differently from what lactic acid, introduced from outside, is known to do? If, however, lactic acid is to act on the bones, it cannot reach them except through the circulation. Neither lymph nor blood is acid, and certainly contains no lactic acid. Thus certainly the bones are in perfect safety so far as any danger on that score is concerned. The theory that formation of lactic acid is a sufficient cause for rhachitis, inasmuch as it washes out the phosphate of lime from the bones—a theory which has been upheld by our townsman, Dr. Heitzmann—is therefore much less plausible than it looks on first sight. For it is true that lactic acid will dissolve bone in the tumbler; but in the organism it cannot get at the bones; it is decomposed before it is ready for an attack. Besides, rhachitis is by no means a simple chemical process. If it were, we could change a healthy bone into a rhachitical one in a chemical laboratory.

leaves the intestine in a saponified condition; a second part, as free, fatty acid; a third, as fat in an unchanged condition.

Where no food is given but mother's milk, which contains fat in proportionately smaller quantities than cow's milk, and finely suspended and easily absorbed, *a good deal of fat is eliminated.*

There is no sugar in such fæces, but a great deal of mucine. What has been called milk detritus in the fæces is not all undigested casein, but, on the contrary, it is mostly fat, and very probably remnants of intestinal epithelium. This milk detritus, so-called casein, and mainly consisting of olein, margarin and stearin, is not soluble in water, acids, or alkaline, but very soluble in alcohol and ether.

Practically this fact is of the very greatest importance. Fat is not completely absorbed under the most normal circumstances. Fat-acids are easily formed, and accumulate to such an extent that they are found in moderate quantities in even the healthiest nurslings. Superabundance of fat-acid is a common derangement of digestion and assimilation, and it impedes the previously normal secretion of other digestive fluids. Thus there is a *plus* of fat, even in the normal food of the nursling, the breast-milk.

The conclusion, then, is that we have to be *very careful in the preparation of artificial food. It is almost certain that we give too much fat; it is scarcely ever probable that there is too little.* Therefore the addition of cream is reprehensible, no matter in what shape. Whenever cream and cream mixtures have been recommended, inventors and backers have always made the statement that such mixtures are, "as a rule," well tolerated. It is a doubtful praise, however, that food should be simply well tolerated, "as a rule." The fact alluded to has probably been the cause why Liebig has, in his artificial food, only *forty* per cent. of the fat contained in mother's milk.

Fourth.—The addition of water to cow's milk, boiled or not, with or without the addition of sugar, has always been the first means of rendering cow's milk more similar to woman's milk. The thousands of recommendations of measurements and percentages found in books and journals are but repetitions of what women of all countries have put in practice. There are many large institutions in which children are not given any other food except this mixture of milk and water. Is this addition beneficial, indifferent, or injurious? Is it useless ballast, molesting the skin and kidneys, and soiling linen, or does it mean something else?

The influence of absorption and elimination of water has been thoroughly studied. Water and urea stand in a positive relation to each other. Bischoff found an increase of urea with an increase of elimination of water through the kidneys in man and in the dog. Genth experimented upon himself with the same result.

Whenever animals are to be fattened, water is refused. The accumulation of fat is the result of a morbid condition. Neither the child nor the adult, however is to be fattened. Where lively metamorphosis of tissue is required, water is indicated.

Not only is water necessary as regards elimination, but also for digestion and particularly for secretion of an effective pepsine. The amount of secreted pepsine depends to a great extent upon the nature of the ingesta. It is considerably increased by injections, into the veins, of solutions of sugar, of digested meat, and particularly of dextrine. Such is the effect of soup taken before our meals. As soon as milk is introduced into the stomach, water and the dissolved sugar and most of the salts are absorbed and pepsin is secreted.

Butter does not find its digestive element in the stomach, but must wait for the action of the bile and the pancreas in the intestinal tract. Casein, however, remains in the stomach to wait for the influence of the digestive fluids, which require a large amount of water. It is an old observation that water facilitates the digestion of casein.

When, in experiments, digestion ceases, the digestive process recommences as soon as water is added, with an increased secretion of pepsin. Any cause rendering milk more concentrated disturbs digestion; therefore condensed milk requires great dilution. Frequency of nursing at the breast of the mother or wet-nurse renders milk condensed and indigestible by increasing the amount of casein.

Hot weather, fever, menstruation of nursing women, all have the same effect. While the secretion of acid in the stomach depends mostly upon the introduction of solid substances, the formation of pepsin depends probably upon the introduction of liquids.

When adults do not tolerate liquids, the cause is to be sought for in the improper relation of acids and water, which should be about four parts in a thousand. The introduction of a small quantity of muriatic acid, or, perhaps better, of solid food with chloride of sodium, will be the remedy. This disproportion is not so frequently met with in children. They have a natural tendency to the formation of acid. Milk-sugar turns into lactic acid at once. A very trifling digestive disorder, resulting from changes in the digestive surface or in the introduced food, results in the secretion of mucus and the production of acid.

The presence of large quantities of farinaceous foods is still more apt to give rise to fermentation and the formation of acids. Children who partake of them indiscriminately and freely, suffer a great deal from a superabundance of acid in the whole intestinal tract, but scarcely from the absence of acid. Now, in addition to this, it is a fact that infants, as a rule, are not given water to drink. We, moreover, know that in the *first* few months of their lives but little liquid is secreted in the mouth which might have a local effect in the stomach. Thus we can say, positively, that infants are very much more *liable to have too little water in their food than too much.* This is the most important reason why the food of infants should be given in great dilution—in greater dilution, certainly, than the usual rules found in the books would permit. At all events, it is well that children should have plenty of water in their food. We must not forget that, as a rule, they obtain it only in their milk. No matter whether it be winter or summer, hardly ever is there a mother or a nurse who imagines that a child can be thirsty without being hungry at the same time. Much discomfort and a good deal of sickness is a result of the fact that infants must eat in order *not* to be thirsty, and have frequently to go thirsty because an over-exerted and disordered stomach will not accept any more food. That has been the reason why in the rules and regulations for infants, as published by the New York Board of Health for the last half-dozen years, I have impressed upon the minds of mothers the necessity of now and then giving some water to their children.

Fifth.—The casein of cow's milk and the casein of woman's milk are two different substances. When isolated by alcohol, by which both are thrown out of their combinations to a certain extent, the chemical properties are found to differ widely. Thus obtained, cow's casein, when moist, is white; when dry, yellowish. It reddens litmus-paper, and acidulates water, in which it is soluble in the proportion of 1–20. Woman's casein, however, in its moist condition, is yellowish, alkaline, or neutral, and dissolves almost entirely in water, the solution being of neutral reaction. Vierordt and Biedert found the quantity contained in the two milks to differ, there being less in woman's milk than in cow's milk.

When exposed to artificial gastric juice they also act differently. In a surplus of it woman's casein is dissolved in a short time; cow's casein in twenty-four hours. Mineral acids, lactic acid, acetic acid, tartaric acid, Epsom salts, phosphate of lime in solution, coagulate cow's milk in hard and dense masses; not so human milk. Solutions of both kinds of casein in alkalies show many similar properties; but the sediment produced by the addition of lactic acid can yield essential differences. Thus there is a chemical as well as a physical difference between the two species of casein. Although their relation to artificial gastric juice has not been found to differ to that extent by Dr. C. P. Putnam, of Boston, it is upheld by a number of other observers, and the fact becomes clear that pure cow's casein is very much less digestible than human casein. At all events, it should be so considered, and infants should have only as much casein as proves digestible. One of the alleged means of combating the improper effect of casein, as has already been stated, is to increase the relative amount of fat by adding it to the food. It is true that in this way a more proper relation of the two can be obtained, but certainly no more proper relation of the two to the insufficient condition of the infant digestive organs.

Besides, the addition of cream to either casein or fresh milk has something very doubtful about it, as at the time when cream has formed upon milk, by simply allowing it to stand, the formation of lactic acid is going on all the time. At all events, no addition we know of can render cow's casein more digestible than Nature made it, and the only thing which can be obtained by any sort of treatment of the milk is to make it less injurious. Perhaps, however, the plan upon which Dr. J. Rudisch has acted may recommend itself to the attention of the practitioner. In order to make cow's milk more digestible, he has introduced into my practice a mixture which promises to be of great value in all those cases in which coagulability of the milk is the prominent obstacle to its usefulness. The mixture suggested by him, and used by us up to this time mainly in diseases of adults, such as anæmia, gastric catarrh, ulcer of the stomach, slow convalescence, etc., is the following: to one pint of water one-half teaspoonful of officinal dilute muriatic acid is to be added. To this mixture add one quart of raw cold milk; mix the two liquids thoroughly and then boil for ten or fifteen minutes. I have found this preparation to be very digestible, and tolerated well by very feeble digestive organs. Clinical experience not only favors this preparation, but it is also favored by direct experiments. When liquid pepsine is added to common milk, coagulation takes place very rapidly, and in thick coherent masses. The same liquid pepsine, when added to the above mixture, produces so slight coagulation that it can scarcely be observed. The coagula also are small, and do not adhere firmly to each other. Essence of rennet coagulates common milk speedily and completely; the above mixture more slowly and not so completely. The coagulation of common milk exhibits, after a certain time, thick, dense, and firmly coherent masses. The coagula produced by the above mixture are fine, loose, and are easily separated when the liquid is shaken.

Valuable as this preparation of cow's milk may prove in future, there is one method for making cow's milk more available, which is at once simple and effective. No cow's milk ought to be administered without the addition of chloride of sodium. Not only cow's milk, but also—and even much more so—farinaceous admixtures to cow's milk require its presence in the food.

Chloride of Sodium.

The part which salt plays in nutrition is an exceedingly important one. It is a well-known fact that animals which receive a certain amount of salt (30–50 grms. to a weight of 1,000 lbs.) are disposed to take a larger quantity of fodder than without it, and that the fodder is not only improved thereby in taste, but apparently also in its nutritive effect. "But we have little positive knowledge as to whether the salt promotes the digestibility of the fodder, or certain of its component parts, or whether it has no effect in this respect" (E. Wolff). The fact undoubtedly is that the presence of the salt, by inducing greater activity in the chemical changes, causes an increased demand for food; the food already in the intestines is better digested and absorbed, and, when excreted, it has undergone greater modifications. Carnivorous animals have not the same need for salt as the herbivorous. The food of the latter, while containing all the other mineral substances necessary to the animal organism, and in more or less appropriate combinations, is relatively deficient in salt. There is a marked disproportion between the sodium and potassium. The amount of sodium and chlorine in the food of carnivora and herbivora is about the same for each; but the food of the herbivora contains twice or four times as much potassium as that of the carnivora. Hence, an accumulation of potassa salts (phosphatic, etc.) takes place in the blood; this accumulation requires the chloride of sodium to neutralize them, so that they may be eliminated. When Bunge[1] took large quantities (18.24 grms.) of phosphate and citrate of potassa for two days, he lost half of his sodium in circulation. On the next day very little was excreted, because he had first to make up for the loss.

In this connection it should be borne in mind that vegetable food contains more potash (and less soda) than milk, and the milk of herbivora more than the milk of carnivora—facts of vast importance with regard to the preparation of artificial food for the human suckling.

In the infant body the physiological effect of salt is both immediate and remote in its character, whether it be supplied directly in the mother's milk, of which it is an important component part, or is added as a seasoning to vegetable food. A portion of the salt taken may be absorbed in solution, but a portion is unquestionably decomposed to form another soda salt and hydrochloric acid (Beneke). The latter, which is a normal ingredient of the gastric fluid, serves directly as a stimulant to the secretion of the glands, facilitates digestion and excites the appetite. The superabundant acid that passes into the intestinal canal unites with the soda of the bile, which it meets in the duodenum, forming chloride of sodium again, which, in turn, is dissolved in the fluids. Here now begins its chief function, which consists in the osmosis from the surface into the villi and blood-vessels; from the villi into the blood; from the serum into the blood-corpuscles; from the blood into the tissues, and back again. The homogeneous albuminoid substances do not penetrate the cellular walls or interstices, but the heterogeneous, crystallizable substances in solution can penetrate them, bearing with them also the albuminoid bodies, both into and out of the cells. Everywhere it is the salt which renders possible the processes of development, both progressive and retrograde. Moreover, the effect of salt, in very moderate quantities, is apparent to the chemist and to the clinical observer. More water will be excreted from the kidneys, though no more has been supplied to the body by drinking. And without more water being ingested the amount of urea will be increased, that is, the metamorphosis of albumen will be increased (by 4.7 per cent. when ingested in moderate quantity), in consequence of the more rapid flow of the parenchymatous fluids. Of course rapidity of the flow will depend upon the amount of salt present. A large amount will hasten the metamorphosis of albumen, and necessitate the ingestion of more water, thereby increasing the excretion of urea and carbonic acid; hence, at the same time, it will diminish, on the one hand, the amount of albumen in the tissues and in circulation, and, on the other, the respiratory material—the carbohydrates. Further than this, they stimulate the surface secretion in an enormous degree. In the *Journal für Kinderkrankheiten* of the year 1873, an example of mother's milk is mentioned, which contained eight per cent. (!!) of salt, and, before the discovery of the cause, the suckling had been brought by diarrhœa to the borders of the grave.

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[1] Zeitschr. f. Biol., IX., 104, 1873; X., 127, 295, 1874.

Animal Substitutes for Milk.

Certain writers have recommended that when milk alone or milk mixed with water has failed to produce a satisfactory state of nutrition, an animal diet—meat-broths, eggs and milk, etc.—should be resorted to at an early period.

Milk and Meat-broths.—Bretonneau reported, as early as 1818,[1] that, when children in the hospital at Tours, who were suffering with "tabes mesenterica," were fed with milk and meat-broth, they got well of the disease. Vaucquelin found that a mixture of cow's milk and meat-broth was the next best thing to woman's milk. Jäger also recommends this mixture, but with the very ambiguous remark that the addition of farinaceous material to cow's milk makes "vegetable milk still more vegetable," adding that when children are fed with meat-broth and milk the teeth seldom appear before the eighth and usually not before the twelfth or sixteenth month; but we are finally assured that the nutrition of the bones is not thereby disturbed, and that that of the teeth is actually improved; for, though the eruption of the permanent teeth is delayed, when they finally do appear they are all the better developed.

Beef-tea.—In connection with the above recommendations to combine meat-broth with the child's milk or with its food generally, I deem it opportune to call attention to an article of diet by which unquestionably a great deal of harm has been done. I refer to beef-tea. It has come very largely into use in practice among children both in this country and in Great Britain. In Germany, too, it has found very many advocates, and among some who have abandoned the obsolete notion that when prepared in the customary way it contains a large proportion of protein in its composition. It must be remembered that this form of meat-extract contains a very large amount of salts, and that the direct effect of these upon the intestinal canal may be productive of very unpleasant consequences. It is a mistake to give it when the intestines are irritated or very susceptible of irritation, for the reason that diarrhœa is apt to directly follow its use. Nevertheless, I have often seen beef-tea given under these very circumstances with no other object than the vain one of furnishing the child with a great amount of nourishing food. This is very commonly done during the obstinate and exhausting diarrhœa of summer. If the people insist upon giving it, and there is no special contraindication to its use, it should be administered only in connection with some well-cooked farinaceous vehicle, and the best of all for this purpose is barley-water; or it may be mixed with beaten white of egg, but no more salt should be added. For the main danger in beef-tea is the concentrated form in which its salts are given. They must be expected to result in diarrhœa. This "beef-tea," so common with us, must not be mistaken for the beef-tea as recommended by Liebig, which is but a maceration of beef in cold water with a small amount of muriatic acid.

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[1] Nouv. Journ. Med.-Chir. Pharm., Août.

A vast improvement of this has been introduced into my practice by Dr. Rudisch. Some ounces of tenderloin, very finely cut, are macerated, and frequently stirred, in a tumbler full of water (6 or 8 ounces) mixed with 6 or 8 drops of diluted muriatic acid, for about an hour. After that the mixture is boiled ten minutes. Not only is the taste pleasant, but the percentage of the active constituents of the decoction is much greater.

Buttermilk.—Buttermilk also has been regarded as an important element of the infant's diet. While others insisted upon the necessity of increasing the amount of butter in cow's milk, Ballot removed the butter entirely. To a litre of buttermilk a spoonful of fine wheat flour was added; the mixture was then boiled for a few minutes until a thin gruel was made; 0.8–1 grm. of sugar was added. If diarrhœa occurred, rice was to be used in place of the flour. It is not stated whether diarrhœa was expected as a matter of course, or whether wheat flour and rice are to be taken as the equivalents of each other. This diet was begun as early as the third week after birth, in order that the child might become accustomed to it sufficiently early. Ballot gave it to his own children, and many followed his example. It is stated also that the same mixture was given to the nursing infants in the Children's Hospital in Rotterdam. A. Van Mansveld also claimed to have had good results with it in three cases.

Egg Mixtures.—Beno Martini gives a recipe for a mixture of yolk of egg and sugar with water, which is intended as a substitute for mother's milk, for a later period, when the child's age would correspond to breast-milk of the following composition, viz.: water, 87–90 parts; fat, 2–4; protein, 1½–3. He proposes another mixture, which he claims to have tested. It is composed of one yolk of egg (15 grms.), 100 grms. of water, and 6 grms. of milk-sugar, which is equivalent to water, 89; fat, 3.7; protein, 2.0; milk-sugar, 5.0. A little chlorate of potash should be included in this, inasmuch as the albumen of hen's egg contains no potash, though doubtless a sufficient amount of the phosphates.

A recipe somewhat similar to the above is that of C. A. Coudereau. It is as follows: sulphate of potash, 0.5; bicarbonate of soda, 1.0; honey, 100; water, 300; 8 fresh eggs (=375 grms.). These ingredients are to be well shaken together, and, finally, 250 parts of lime-water are to be added.

During the siege of Paris, Bouchut recommended this mixture: the yolk of an egg with a little white of egg, and 15 grms. of cocoa butter, to be beaten together, and one-half litre of warm sugar and water to be then added. At the same time, Dubrunfaut gave the following recipe: half a litre of water of a temperature from 50° to 60° C., 40–50 grms. of sugar, 20–30 of dry albumen, 1–2 of soda, and 50–60 of olive-oil. Gelatine might be substituted for the albumen in this emulsion. Tua proposed horse-fat instead of olive-oil. Gaudin recommended the fat and also the gelatine that is obtained by boiling bone. We doubt, with Sanson, whether oil is as digestible as the butter of breast-milk. We congratulate ourselves, indeed, that the circumstances of the times do not give rise to such want and general distress as to necessitate a resort to such extraordinary mixtures as these.

The egg-drink recommended by Hennig consists of 200 grms. of boiled water, with which a fresh white of egg is beaten at a blood-heat, and a little salt is added. If the child was somewhat advanced in age, raw yolk of egg and milk were added. The mixture answered very well in case of diarrhœa. Raw white of egg was added advantageously to any kind of infant's food where there was diarrhœa. Hennig does not, however, urge its employment in all cases, and refrains from promising any wonderful effects. I am personally convinced that his recommendation of the white of an egg is not overdrawn. For twenty years I have often fallen back upon it as a valuable aid in saving life. In the many instances in which cow's milk is not tolerated, the white of an egg comes in as my sheet-anchor, principally in the severe cases of gastro-intestinal summer catarrh, in which milk is not tolerated at all, and must be discarded entirely. In such cases I mix the white of one egg with a cupful of barley-water and a little salt, and usually sugar; on special indication, with the required dose of brandy. Of this the baby takes a teaspoonful every five or ten or fifteen minutes. In this place I will merely say that I know that I have saved many a baby's life in this manner.

Vegetable Substitutes for Breast-milk.

When animal substitutes proved unavailing, or could not be obtained, vegetable ones were looked for. Great difficulties arose from their composition and indigestibility. Particularly is it the starch contained in vegetable substances which proved an obstacle to their use. We need not refer here to the history of the attempts of proving their usefulness or injuriousness, nor to the millions of infants that have been, and are, immolated on the altar of ignorance and recklessness. What concerns us here is the question, to what extent—according to physiological laws—starch, or substances containing starch, can be used as infant food, or as additions to infant food.

After a number of experiments and literary statements of Bidder and Schmidt, Ritter von Rittershain, Jörg, and myself, Korowin made a number of experiments for the purpose of comparing the effects of the salivary glands with those of the pancreas. He treated starch with infusions of both the pancreas and the parotid glands. The result was this, that the pancreas obtains the power of transforming starch into sugar at a later time than the parotids. No such effect was exhibited by the pancreatic infusion in the first month, but a noticeable one in the second, and a measurable one in the third. At the end of the first year the diastatic effect of the pancreas is fully developed. The parotid infusion, however, is effective from the first day of life, particularly in well-developed infants. Small pieces of sponge were introduced into the baby's mouth, and withdrawn after a while. It took from fifteen to thirty minutes to collect a cubic centimetre of saliva in the mouth of infants of from two to four weeks, the tenfold time of what was required in infants of three months. Now and then the secretion would stop, after having been distinctly active, for a little while. Seventeen babies, of from one to ten days, yielded a diastatic saliva. The number of his quantitative experiments amounted to 120. The diastatic effect of the saliva of an infant of eleven months was as marked as that of his own.

Korowin also published the results of a second series of experiments and observations, with the same results. Zweifel's conclusions are similar, and are besides capable of illustrating certain morbid conditions. The infusion of the submaxillary gland of a young infant yielded no transformation of starch into sugar after an hour's contact. The infusion of the parotid of a baby of seven days proved effective after four minutes, that of an infant of eighteen days who died of gastro-intestinal catarrh, and that of a fœtus of the ninth month of utero-gestation, after forty-five minutes. No diastasis was produced by the parotids of a prematurely born child dead of diarrhœa and debility, of a fœtus of three months, and of one of four months. Thus it becomes evident that age, development, or sickness, with diminished amount of fluid, is of great moment in changing the diastatic effect of the salivary glands. Still it is evident that from the first days of life starch, in *small* amounts, can be digested; that in a few months after birth such vegetables as contain starch in moderate, but not overwhelming percentage, may be used as additional infant food. At the same time, we must not forget that it is not absolutely necessary that every particle of ingesta should, in all instances, be digested and assimilated. That is impossible; the very breast-milk contains such amounts of fat, for instance, that it cannot all be digested and absorbed. The requirement is only that not enough should remain undigested to encumber and irritate the intestinal tract.

Farinacea.

The selection of a diet which is, at the same time, glutinous and nutritious, will not, perhaps, be so difficult as it appears at first sight. The farinacea, which chiefly contain starch in large quantity, such as potatoes, rice, and arrow-root, must naturally be excluded. I have employed very few of the large number of these articles, selecting them for the great quantity of protein substances which they contain.

Moleschott gives the following data:

Protein substances in wheat, 135; barley, 123; rye, 107; oatmeal, 90; maize, 79; rice, 51.

Starch in rice, 823; maize, 637; wheat, 569; rye, 555; oatmeal, 503; barley, 483.

Fat in maize, 48; oatmeal, 40; barley, rye, wheat, very little.

Salts, chiefly phosphates, in barley, 27; oats, 26; wheat, 20; rye, 15; maize, 13; rice, 5.

Potash is found especially in wheat, magnesia in wheat and maize, lime in grits and barley, iron in barley, phosphoric acid in barley and wheat.[1]

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[1] The table compiled by Barrett from Peligot, Fresenius and Boussingault, gives the following results, which are quite accurate in most details:

Maize and rice must be excluded from the list given below, on account of their large percentage of starch. Barley, wheat, rye, or oatmeal are preferable for their large percentage of protein substances; barley, oats, and wheat, for their richness in salts; iron is only present, in appreciable quantities, in barley and oatmeal.

Wheat, barley, and oatmeal present a favorable history. Even during the reign of Charles I., when wheat was almost unknown in the north of England, barley formed the ordinary diet. Even at the present time these grains form the chief sustenance in many districts of northern Europe and the south of England, in Wales and Scotland, and of ninety per cent. of the urban laboring classes in England. Formerly the retinue of the English nobility, and almost the entire agricultural population of England and Scotland, lived almost exclusively off oatmeal (Letheby on Food, p. 11). Moleschott states that thirty-six ounces of barley are sufficient nutriment for a hard-working man. Dujardin and Beaumetz (and afterwards Dussein) are enthusiastic champions of oatmeal and of its great importance in the nutrition of infants. They recommend the use of the Scotch cereal. After being threshed, the grain should be dried in a stove, the husks removed, and the grains should be crushed rather than ground. The fine strained meal is the part used for children. They found the proportion of the nitrogenized to the non-nitrogenized substances in this meal as 10 : 38 (in woman's milk, 10 : 35; in cornmeal, 10 : 50), and they lay especial stress upon the amount of iron in oatmeal, which far exceeds that contained in wheat bread or in cow's milk (0.0131 as opposed to 0.0048, or 0.0018).

The list of farinaceous articles has not been exhausted, but there are none others which conform better to our conception of an ideal nutritive substance (one part nitrogen, three to four non-nitrogenized elements). Wheat flour has been employed in the preparation of most children's foods. It contains more starch than barley or oatmeal, and has, therefore, given rise to real or pretended endeavors to convert the starch into dextrin and sugar before its passage into the stomach. The smaller quantity of starch in barley and oatmeal renders this superfluous, and they can be employed in commerce without previous preparation. Oatmeal was particularly recommended by the earlier writers as a form of infant diet. Van Swieten bestows especial praise upon it, and T. Herbert Barker placed it at the head of articles of diet.[1] I have always preferred barley whenever it be-

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	Wheat.	Barley.	Rice.	Rye.
Water	13.6	13.9	7.3	14.7
Starch	60.8	48.06	83.0	65.1
Dextrine, sugar	10.5	7.62	...	...
Gluten	12.5	13.18	7.15	12.5
Fat	1.1	0.34	0.7	2.0
Cellulose	1.5	13.34	1.0	3.3
Salts	...	3.56	0.5	2.4

[1] "In placing oatmeal gruel at the head of the list of farinaceous foods I am guided by my own observation of its utility. Such, indeed, is my confidence in its value that if

came necessary to recommend a particular article of diet, because oatmeal, on account of its larger percentage of fat and mucin, is more liable to relax the bowels. In other respects the chemical composition of each is so nearly the same that it would be immaterial whether we chose one or the other. But there is no danger to which little children are so liable as that which arises from their tendency to diarrhœa. My advice, therefore, is to administer barley to children who manifest a tendency to diarrhœa, and oatmeal to those having a tendency to constipation, and, whenever a change occurs in the intestinal functions, to give one or the other, according as constipation or diarrhœa predominates. Its practical importance will sanction the introduction in this place of the remark that *diarrhœa and milk-diet are incompatible*, and that, therefore, when barley is employed on account of the presence of diarrhœa, it is advisable to immediately reduce the quantity of milk present in the nourishment, or to temporarily abstain from its use altogether. In such a case the raw white of egg (with or without brandy) may take the place of the milk. This practice has carried me through many dangers during the last twenty years, and has saved the life of many a child. I have noted with pleasure the success which H. Demme has obtained by a similar practice in the Child's Hospital of Berne.

I will here add, also, another remark. In my "Infant Diet" I maintained that it was immaterial whether we employed the ordinary commercial barley or the smaller grain which had been deprived of the husks. This was a mistake. I had been led to believe that the protein substances and the starch were uniformly distributed in barley. Their relation is, however, the same as that observed in other grains, *i. e.*, the much larger part of the gluten is accumulated in, and directly underneath, the superficial layers. According to Enzinger's[1] latest investigations and plates, the body of the barleycorn immediately adjacent to its covering membrane is composed of large, irregular cells, which contain albuminoid substance and no starch. Toward the centre are found larger, irregularly quadrilateral cells, which contain albumen and a large quantity of starch.

I were restricted to the use of any one article, in addition to milk, for bringing up a child, it should be this." If bad companions would injure a good cause I should not refer to the opinion of Mrs. Baines, who insists upon the use of farinaceous articles because, since the food of man and beasts is different, milk must differ in accordance with that difference. "When this idea will be thoroughly understood, and this great fact of natural history recognized, we will understand the advantage of a combination of vegetable substances with cow's milk as the most suitable article of infant diet."

[1] The membrane covering the barleycorn consists of small, thick-walled cells, whose walls are poor in water and imbibe it with difficulty. This imbibition is rendered still less by the presence of fat. The yellowish color is due to the presence of extractive matters. The husk of the barleycorn is adherent to the basal bristle at that end of the corn at which the root-seed breaks through. The bristle opens into the centre of the barleycorn by prolongations, which look like capillaries, run inward, and possess great power of imbibition. A second covering is devoid of a thickened layer, and readily imbibes water; it lies within and parallel to the first covering, except at the place where the root-seed makes its exit. A third covering is bent inwardly from the preceding.—Lorenz Enzinger: Die Anatomie des Gerstenkornes, Leipzig, 1876.

More internally are found even larger cells, which are almost entirely filled with starch. The conclusion to be drawn from this arrangement is, therefore, that the entire barleycorn, and not alone its inner part, must be employed as an article of diet. The prepared commercial barley, which has been previously made ready for use, is characterized by its fineness and whiteness. But these qualities are suspicious characteristics; the less the quantity of the yellowish glutinous outer layers which the barley contains, the less is it to be recommended. The prices of the grain vary in such a manner that adulteration by refining pays very well. I would, therefore, recommend that the barleycorn which is employed for infant diet should be ground as thoroughly as possible in a coffee-mill, both in order to diminish the period necessary for cooking it, and also in order to retain the gluten. *It is even preferable, for very young infants, to cook the barley whole for hours,* thereby to burst the outer layers of cells, empty their contents, and then, by straining, to get rid of the larger part of the starch which is found toward the centre. The next best method consists in crushing the whole grains of barley, and not to employ the so-called pearl barley, which is barley minus husk. At a more advanced period of life the latter preparation, with its greater amount of starch, will suffice.

The addition of barley or oatmeal to properly prepared milk presents certain advantages with regard to the amount of nourishment, since, if Moleschott considers the ingestion of thirty-six ounces of barley as sufficient for an adult laboring man, the addition of half an ounce, or one ounce, of this article is not an insignificant amount for a young child. C. Voit has recently made an exhaustive study[1] of the nutritive demands of children at a certain age. Semler (*Ernährungsbilanz der Schweiz,* p. 6) found that the proportions of the nutritive elements in the food of children up to the age of fifteen years were such that there were 79 grms. of albumen to 20 grms. of fat and 250 grms. of hydrocarbons (nitrogenized: non-nitrogenized = 1 : 3.8). For children from the ages of six to ten years Hildesheim found 69 grms. albumen, 21 of fat, and 210 of hydrocarbons (1 : 3.6). In the Munich Orphan Asylum, in which the children, who are subjected to both bodily and mental labor, present a healthy appearance, Voit found that the nutriment contained 79 grms. albumen, 35 grms. fat, 251 grms. hydrocarbons (1 : 3.9). Finally, he has carefully estimated the relation which exists between the nutriment required by a child and by an adult (working and resting).

	Albumen.	Fat.	Hydrocarbons.
A child, æt. 10–11 years, 23 kilogrm., requires.	79	35	251 = 1 : 3.9
A laboring man of 60 kilogrm., average......	118	56	500 = 1 : 5.0
" " " at work......	137	173	352 = 1 : 4.7

While resting, the proportions are as follows :

	Albumen.	Fat.	Hydrocarbons.
1,000 kilogrm. child................	343	152	1,091
" " adult...............	228	120	586

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[1] Ueber d. Kost in öffentl. Anstalten. Zeitschr. f. Biol., XII., I., 1876.

We therefore find that, in the child, given weights of tissue which must carry on the nutritive processes, and, at the same time, appropriate albumen, fat, and salts, require a larger amount of albumen, fat, and hydrocarbons than the same weights in the adult when in a similar condition of rest. 50 per cent. more of albumen, 25 more of fat, and 100 more of hydrocarbon, are required than by the adult. But they must not be merely administered to the child; they must also be given in an easily digested form. In very young infants they should be given in the same or similar condition in which they are found in the milk of the human female, in which the proportion of nitrogenized to non-nitrogenized ingredients is as 1 : 2.7. We should not deviate too far from these proportions. J. Forster has given the following table :

AGE.	Diet.	Albumen.	Fat.	Hydrocarbons.	Proportion.
7 weeks	Pap.	29	19	120	1 : 5.3
4–5 months...............	Swiss milk.	21	18	98	1 : 6.1
1½ years...............	Mixed.	36	27	150	1 : 5.4

The large proportion of 1 : 6.1 is undoubtedly attributable to the large quantity of sugar which "Swiss milk" contains. To what extent this sugar is useful, immaterial, or injurious, has been previously referred to. It can easily be shown that, under certain circumstances, it may be useful, that occasionally it is injurious, and that it is rarely an indifferent substance. It is too soluble and changeable, and too readily absorbed, to be an indifferent article. It differs greatly in this respect from a small quantity of starch which may pass harmlessly through the intestines.

In connection with this subject, and with farinaceous foods, or admixtures to infant food, I shall refer to a few substances the nature and effect of which have long been doubtful, but which have been more or less used among infants and children as food, or as an addition to food.

Gum-arabic.

Frerichs, Lehmann, and Husemann do not admit that any change occurs in gum-arabic in the human body. Gorup-Besanez believes in its solubility, but not in its digestibility; hence, if gum-arabic is an important aid in digestion, it is for one reason only, namely, that it acts mechanically, and renders the coagulation of milk less dense. Of late, however, Uffelmann has made some experiments with a solution of gum-arabic of the strength of *eighteen* parts of the gum to *two hundred* of water. His experiments were made upon a boy upon whom gastrotomy had been performed, thus affording opportunity for making direct observations. When he introduced this solution into the boy's stomach, he found grape-sugar after some time, no saliva being present. The same transformation has been observed in the Munich laboratory. The experiments were published in the *Jour. f. Biol.*, Vol. X., p. 59, 1874.

Fifteen grammes of the above solution yielded *five* centigrammes of grape-sugar after forty-five minutes; *thirty* grammes gave *twenty-eight* centigrammes after *sixty* minutes. The liquid taken from the stomach in the latter case was very acid indeed. It matters not whether this acid was inside of the stomach previously, or was developed during the presence of the gum-arabic solution; in both instances it appears that the development of muriatic acid and the transformation into grape-sugar go hand in hand. It is possible, then, that it will be found practical, in those cases in which the object is not simply to mix milk with gum-arabic, but also to derive benefit from the digestion of the gum, to add a small quantity of muriatic acid.

Gelatine.

Gelatine, in the opinion of many, when combined with milk fulfils two indications. The one is the same as that obtained by the glutinous condition and effect of gum-arabic and farinaceous articles; the other is found in its usefulness as a tissue-building material. Guérard quotes Jean de Lery, who speaks as follows: "Ayant expérimenté que cela (skins, parchemin) vaut au besoin, tant que j'aurais des collets de buffles, habits de chamois, et telles choses où il y a suc et humidité, si j'estois enfermé dans une place pour une bonne cause, je ne me voudrois pas rendre pour crainte de la famine." Papin is reported to have made the offer to Charles II. of England to furnish for the use of poor-houses and hospitals "un quintal et demi de gelée" with "onze livres de charbon." This offer was refused because a dog was paraded before Charles wearing a sign-board containing said dog's request not to be deprived of his mess of bones.

The French Academy of Medicine has taken great pains to discover the properties of gelatine. After Magendie in 1848, Vrolik in 1844, Bérard in 1850, and Edwards and Balzac, had published their reports upon the subject, Guérard comes to the following conclusions: 1. That gelatine is very nutritious; 2. That very probably it is of great importance in the process of building up cellular tissue, therefore absolutely necessary for the preservation of life. Frerichs, Metzger and de Bary, Schroeder, Kuehne, and Etzinger, found that gastric juice changes gelatine in such a manner that it loses the property of gelatinizing. This effect was not produced when it was treated only with muriatic acid. On the other hand, Imthurn also attributes the effect to the influence of muriatic acid. It is true that Meissner and Kirchner have entirely denied the changeability of gelatine by means of gastric juice. But Gorup-Besanez is of the opinion that gelatine is peptonized in a similar manner with the albuminates. It seems that Uffelmann has also finally settled this question. He found, in the gastrotomized boy, *first*, that while feverish, and again without fever, the gelatine was speedily dissolved in the gastric juice. It was so modified at the end of one hour that it would no longer coagulate, and was easily diffused. To produce this change by means of artificial gastric juice, he found that from eighteen to twenty-four hours were necessary, and in both instances there was no offensive odor. When the experiment was performed inside of the stomach, he occasionally observed the presence of grape-sugar. When that occurred the temperature of the body was elevated. No grape-sugar was ever found when the gelatine was exposed to the action of artificial gastric juice. Gelatine digested in gastric juice retains its essential chemical properties. It resembles peptone inasmuch as it is not precipitated by acids, and polarization results in turning to the left. It differs from peptone inasmuch as its diffusibility is less, and, when dissolved in acetic acid, it can be precipitated by ferrocyanide of potassium. It is so much like peptone that its digestibility can hardly be doubted, not to speak of the direct observations made by Uffelmann. There is one point, however, not to be lost sight of, and that is that it is apt to putrefy, and therefore requires the addition of a small quantity of muriatic acid. The latter point is of great practical importance; for, in acute diseases, in slow convalescence, in anæmia, the secretion of pepsine and muriatic acid is very much limited. For that reason muriatic acid should be added whenever gelatine is given.

Infant Foods offered for Sale.

The attempts to prepare infant foods by the wholesale, to have them ready at any moment, for the purpose of either benefiting the young infant or the manufacturer, have been very numerous indeed. If I give prominence to a single one, I do so only for the purpose of making some general remarks on that industry, by selecting the one which appears to command the largest sale in the United States. Not that I believe it to be more objectionable than the rest, but because it is impossible, and useless, to fill these pages with the names and titles of patent articles.

Of all the number of "infant foods," but a single one bears the stamp of a scientific name or object. When Liebig prepared his food, he did not pack it up in parcels with descriptive lists and trade-marks, but he published his formula. I have therefore felt justified in considering it in my "Infant Diet."

Intestinal Digestion.

The intestines receive all the cellulose, all of the starch that is not transformed into sugar, all the parapeptones and dyspeptones from protein substances (particularly the casein of the milk), all of the butter, and some of the salts. Some of these materials are simply absorbed, some are digested, and some, either changed or unchanged, are again discharged. One portion of the intestines does not digest; it merely absorbs water and soluble substances. This is the large intestine. Whatever albumen or sugar it takes up is directly excreted again by the kidneys. Hence, when injections are given by the rectum for the purpose of supplying nutriment to the body, the sugar and starch should first be changed into glucose, the milk into peptone, and the fats into an emulsion.

The structure and functions of the infant's intestines present numerous variations from those of the adult. The glands of Lieberkühn are present, but fewer in number and less developed. The submaxillary gland and also the pancreas afford us examples of the fact that organs may exist long before they are capable of fully exercising their functions. The villi of the intestines are generally abundant and large; it is said, even, that they surpass in size the corresponding structures in the adult (Berg). According to the same authority, the capillaries also should be larger (not relatively only, but absolutely) than in the adult. Certainly, Peyer's glands are not numerous, and they are but slightly developed. This insignificant anatomical development answers, indeed, to their physiological, and surely also to their pathological importance; for that important form of disease, of which the affection of Peyer's glands is a specially marked feature, is exceedingly rare at an early period of life, and, when it occurs, is of a very mild character. Abdominal typhus in the new-born infant is almost unknown. I have seen but a single case myself, and scarcely half a dozen well-authenticated cases occur throughout the entire periodical literature. In the later years, from the third year on, typhoid fever is common enough, but usually runs a mild course. For the present, this is all that need be said of the intestinal glands, for the glands of the large intestines have no other function than to secrete mucus. The muscular development of the intestines is feeble. The intestinal canal, from the stomach (which is first called into play when filled with air at the first efforts of the new-born child to swallow) to the anus, is not awakened to sufficient activity during fœtal life to develop its muscular system. According to Zweifel, the occupation of the intestines with meconium takes place by slow successive stages. In a fœtus of three months, both ileum and cæcum are quite empty. At four months, the intestines are filled up to within 2 ctms. of the cæcum. In the fifth month, a few lumps are found in the colon. The imperfect development of the intestines gives rise to a variety of consequences. Gases develop abundantly, are very often neither absorbed nor discharged, and thus produce colic. Moreover, by reason of its feeble development, the muscular apparatus of the intestines is frequently the region where the first symptoms of general disease manifest themselves. Rhachitis very often shows itself in the muscular layer of the intestines earlier than anywhere else, and, when beginning there, runs a very protracted course. Occasionally, too, the tendency to obstinate constipation may be explained by this same muscular weakness. This affection may also be owing to other peculiarities in the infantile intestines. There is a vast difference in length, relatively, between the intestines of the infant at birth and those of the adult.

It is well known that the intestinal canal is developed in the embryo in separate sections. Until the fourth or fifth month there is no colon ascendens, and it is still short even at the child's birth. Notwithstanding this the large intestine of the fœtus at birth is comparatively longer than that of the adult. While in the infant it is always nearly three times the length of the entire body, in the adult it is but twice the length of the body. Equally great is the disproportion in length between the small intestines of the adult and those of the young child. In the ninth month of fœtal life the small intestine is twelve times as long as the length of the body (Meckel), while in the adult it is only eight times as long. Inasmuch as the colon ascendens is very short, and the transversum also not long, the principal part of the excessive length falls upon the sigmoid flexure, which Brandt found to be once only 8 ctms., to be sure, though once it was 24 ctms., but on an average from 14 to 20 ctms. in length. I have myself seen it as much as 30 ctms. long. The great length of the lower part of the large intestine gives rise to a number of convolutions, instead of the simple sigmoid curve, and this may become of great significance. Concerning the position of this portion of the intestines, different opinions have been expressed. Cruveilhier and Sappey regarded the location of the sigmoid flexure on the right side as anomalous. Huguier declares that in the great majority of cases the sigmoid flexure is found in the right iliac fossa. Bourcart states that the transverse position of the colon descendens in the child at birth is exceptional (1 in 5); that in one case in six the sigmoid flexure lies behind the abdominal wall on the right side; that in 150 cases he found it 144 times lying in the left iliac fossa, and that in four per cent. of the cases the sigmoid flexure did not touch the abdominal wall either on the right side or the left, but nevertheless was nearer the left side than the right. Again, Freund believes that in the first year the flexure passes over to the left side, and that prior to this time the rectum, passing up along the median line of the sacrum, turns to the right. My own observations have taught me to look for the (or one) sigmoid flexure in the right side of infants.

Causes of Constipation.

Naturally the great length of the large intestine and the manifold character of its convolutions have a very important bearing upon its function. First of all, they delay the progress of the intestinal contents, facilitate the absorption of fluids, and render the stools dryer and harder. Obstinate constipation is but an exaggeration of this state of things, and sometimes is extremely troublesome. A number of years ago I reported[1] a case in which the prolongation of the colon descendens was so great that the diagnosis of imperforation of the intestines was made. In one case an operation was even undertaken to form an artificial anus. Though such cases and such mistakes are exceedingly uncommon, it must be admitted that there are certain anatomical conditions which by this mere exaggeration may become of serious pathological importance.

In this connection may be mentioned the cases described by Barth and Eisenschitz, where the relations of the abdominal organs, though normal, were in certain respects so exaggerated as to occasion impaction of fæces. In both cases obstinate constipation was produced by the false position of the intestines, owing to a too long mesocolon. This is not the place to go into all of the different causes of constipation in infantile life, which are due to true pathological conditions, and which are described in the text-books. They were made the subject of an exhaustive treatise by Monti some years ago. It is, therefore, not proper to speak here of such cases of constipation as depend upon intestinal diseases, or the use of astringents and opium ; at the most we might refer to those which are due

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[1] Am. Jour. of Obstet., Aug., 1869.

to muscular weakness induced by rhachitis or general debility. Here we are concerned only with the cases of constipation which are dependent upon defective nutrition or inappropriate food. Under the latter may be classed an excess of starch in the food, excess of casein in the milk, and above all, the deficiency of sugar. Insufficient nourishment naturally gives rise to an apparent constipation, but may always be diagnosticated when, in connection with scanty stools which contain little or no casein, there is a marked general atrophy of the child's entire body.

Dietetic Cure for Constipation.

That form of constipation which is owing to an excess of starch in the food will be readily overcome by simply withdrawing the starch; the form that is accompanied with an excess of casein in the composition of the fæces will be removed by boiling the milk and mixing it freely with some form of gruel, in the manner already explained in another place; the form that depends upon a deficiency of sugar may be easily cured by supplying plenty of sugar to the food. By this last-named measure alone, not unfrequently, have I seen long protracted constipation cured, both in cases where the food had consisted simply of the breast-milk, and also in those fed with cow's milk, either alone or in the various mixtures. In the latter case we should simply add a larger quantity of sugar to the mixture; in the former, a lump of sugar is dissolved in warm water, and just before the child is given the breast it is made to drink one or two teaspoonfuls of the concentrated sugar solution.

The feebleness of the intestinal muscular system may give rise to other disturbances. The diarrhœas, which are so common, are occasionally due to this cause. Furthermore, passive secretions take place more easily where the abundant capillary system is not controlled by muscular contraction; and when the muscular layer is thin, it offers less resistance to the passage of the secretions, and becomes œdematous.

In this connection, also, should be mentioned the great irritability of the nervous system in the infant. The paralysis of the terminal nerve-filaments in the intestines in consequence of heat, their irritation through local disturbing influences, and the rapidity with which alarming reflex manifestations occur, remain to be discussed in another place.

The secretion of mucus is very copious; it ferments and becomes sour very readily. The alkaline intestinal juices and the alkaline secretions of the liver and pancreas are easily neutralized, and, in consequence of their decomposition, the matters which should be digested become so much additional material for the production of acids.

Mode of Giving the Food.

How should the infant be fed? From the spoon, from the cup, or from the nursing-bottle? By all means from the bottle. In this way alone can we be sure of having the food of proper consistency, without any lumpy ingredients. By thoroughly mixing and diluting the food we supply in part the place of mastication in the adult. By no means should we yield to the notion so prevalent among nurses and mothers, that the food must be thick to be nourishing. But, above all, it is necessary to its proper digestion that the food be introduced into the stomach slowly and in small quantities. The secretion of the gastric juice taking place a little at a time demands that the stomach be filled slowly and gradually. Even with adults it is a matter of common experience that, when milk is taken as a drink, it is apt to disagree; but, if swallowed more slowly, a tablespoonful at a time, like soup, it is digested without difficulty. Moreover, the act of sucking tends of itself to excite peristaltic action and the secretion of the digestive fluids (Spallanzani, Brown-Séquard). The digestive tract is a continuous canal. The sucking movements call into play the action of the salivary glands and awaken the various other functions of digestion. Twenty years ago, when Th. Ballard sought to prove that nearly all children's ailments and a large proportion of the diseases of women were the consequences of fruitless attempts at nursing ("fruitless sucking"), his extravagant assertions were naturally ridiculed. But he certainly reasoned from a physiological standpoint, which had a basis in clinical truth.

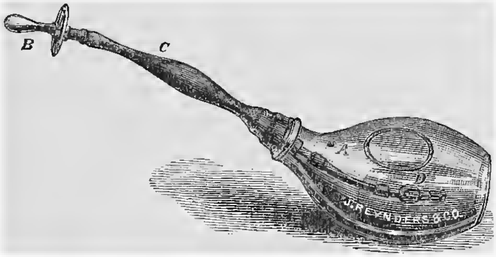
The greatest care should be exercised of course in the management and cleaning of the nursing-bottles. The artificial food, more particularly the milk, is liable to become decomposed even before it is ready for use. When any of the food is permitted to remain in the bottle or upon the mouth-piece, especially if the latter be of rubber, it ferments very quickly, and may thus become a source of danger. Further than this, the kind of bottle used is perhaps a matter of indifference. If the people are cleanly in their habits, the more complicated bottles will be kept clean; while if they are not, the simplest of them will be neglected. Those bottles that have a rubber tube from 16 to 20 ctms. in length, with the mouth-piece at the end, are especially convenient. The rubber tube connects with a glass tube in the bottle, which reaches nearly to the bottom.

Daily experience shows that new-born babies find little or no difficulty in sucking. Those who are not able to nurse owe this incapacity to either muscular debility or to some other anomaly. Muscular debility may depend upon premature birth, or result from sickness and insufficient convalescence.

Another cause of inability to nurse may exist in dyspnœa, from either insufficient expansion of the pulmonary tissue, or from congenital or acquired disease of the lungs, or from heart disease.

Inability to nurse may also depend upon malformations; not so much upon simple, uncomplicated hare-lip as upon double hare-lip, complicated with fissure of the palate. It very rarely depends upon anchyloglosson, though now and then it may be due to hypertrophy of the tongue, or to ranula. In rare cases it also depends upon pseudoplasms of the tongue. I have myself described a case of congenital sarcoma of the tongue, in the American Journal of Obstetrics, etc., August, 1869.

Nursing may also be interfered with by either simple or syphilitic nasal catarrh, giving rise to an accumulation of mucus, or blood, or mere thickening of the mucous membrane; also by different forms of stomatitis—not only the thrush of the new-born and very young infant, but also the erythematous and follicular stomatitis of the infant of more advanced age. To relieve children suffering from this difficulty of sucking, a nursing-bottle has been invented in France, and brought into the market under the name of "Biberon Pompe." I first gave publicity to this instrument on page 413 of the first volume of Gerhardt's *Handbuch der Kinderkrankheiten*, 1877, where I reported that a specimen of the apparatus has been presented to me by Dr. O. Soltmann, of Breslau. Since that time Dr. Soltmann has modified the instrument to a certain extent, and published an account of it in an article entitled "On the Nutrition of Sick Nurslings by Means of a New Nursing-Bottle," *Jahrbücher für Kinderkrankheiten*, etc., Vol. XII., 1878, p. 406. The accompanying woodcut shows that a glass tube inside the bottle carries a small soft-rubber funnel, which is changed into a valve by means of an oblique cut through one-half of its body. Simple pressure upon the mouthpiece, either by the lips or by the alveolar processes, or by the fingers, is sufficient to cause the liquid to escape from the bottle. In cases in which the baby is not able to exert even this pressure, the slightest pressure upon the bulbous expansion of the tube, on the part of the attendant, is sufficient to propel the liquid food into the mouth of the child. The apparatus is to be recommended in just such cases as those enumerated above, not only upon theoretical grounds, but from results derived from actual trial. About a year and a half ago, when I first exhibited the instrument before the New York Obstetrical Society, I had occasion to direct the management of a prematurely-born child with insufficient muscular development; and the infant was fed for months from this bottle, and thrived well.



A, air-hole; B, mouth-piece; C, expanded part of sucking tube; D, funnel valve.

In a case of spinal meningitis, occurring in an infant, and rendering it unable to suck, this bottle was used successfully, and the same can be said with reference to a serious case of follicular stomatitis, in which nursing was an impossibility.[1]

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[1] The bottle is sold by Mr. Reynders, corner 4th Avenue and 23d Street, New York city.

Summary.—After what has already been said, it would be superfluous to go into a critical review of the copious literature of the subject. Writers have not always taken the trouble to support their assertions or theories with physiological or chemical facts. This is true not only of those authors who have addressed themselves to the public at large, but of writers whose works, it is presumed, will be read by physicians. The same directions concerning the diet and management of the child have been handed down from one writer to another. They are just the same, whether the writer be old Metlinger himself, or Cadogan, or those modern authors who write for mothers and for "such as are to be." Not much more can be said of those efforts that have been made to instruct the general public concerning the management of children. Among the best of this kind are the rules issued, five years ago, by the Obstetrical Society of Philadelphia. These rules embraced thorough and judicious advice about washing and warm bathing, avoiding too tight bands and articles of clothing, drying the linen outside the room occupied by the child, maintaining good ventilation, avoiding the danger of nursing the child while sleeping, and about alcoholic drinks, narcotics, etc., etc. But when it came to the question of food, it was quite another thing. Goat's milk was declared to be the best food for infants; next to it came cow's milk. If the child thrives, the rule laid down is, that during the hot weather no other nourishment than milk shall be allowed; and again, nothing shall be substituted for the milk until after the incisor-teeth have come. Under no circumstances is the milk to be skimmed. If, however, as one remarkable rule puts it, milk cannot be digested in any form, then, instead, pure cream, diluted with three or four parts water, shall be given for a few days. The fallacy of these rules will be apparent at once to such as have been led to adopt the views which I have already set forth with regard to goat's and cow's milk. At all events, the rule that nothing shall be used in the place of milk until the incisor-teeth have appeared is decidedly open to objection. Cases of advanced rhachitis, for example, which have developed during an exclusive milk diet, can be cured *only* by an absolute change of food. Again, the delayed appearance of the teeth would afford a contraindication to the exclusive use of milk, but not an indication for its continuance, as the Philadelphia rules would command. The rule, that during hot weather no other nourishment than milk shall be given, is a positively pernicious one. The prefixed clause, "if the child thrives," does not materially modify it. During the hot weather no food is more dangerous than unmixed cow's or goat's milk. In most of the cases of summer diarrhœa, diminishing the amount of milk in the child's food, occasionally even stopping it altogether, is the *conditio sine quâ non* of the infant's recovery. Moreover, the paragraph where it says that when the milk is not digested, cream shall be used instead, is equally objectionable. When the milk is not digested, it is due to the excess of casein and fat which it contains, and to the influence of the heat, etc. To think of exchanging milk, with its ingredients in their natural proportions, for pure cream, is surely irrational. In justice, however, I should add, that in a conversation with one of the signers of the Philadelphia rules, the late Dr. John Parry, that gentleman stated in explanation that his signature had been given too hastily, and he was unwilling that he should be held forever committed to some of the points which the rules laid down.

After all, I again insist upon the principles set forth above, and the mode of feeding as advocated by me, which consists in diluting the boiled and skimmed milk with barley-water or oatmeal gruel. I hold this mixture to be the *conditio sine quâ non* of the thorough digestion of the milk. This only will insure the proper nourishment of the infant. With this food alone I have seen children endure the heat of summer without any attack of illness whatever. It is because I am so deeply convinced of its importance that I revert to the subject here. In this climate, so perilous to infant health, where severe derangements of digestion belong to the most common of the daily experiences of the practitioner, I have had occasion again and again to be convinced of the reliability of my mixture. It has this advantage, too, that it necessitates no dependence upon the honesty or competence of the apothecary and manufacturer, but this mixture can be prepared by any one, however poorly situated. I conceived it to be necessary to discover a kind of food, suitable to the infantile age, which *could not be spoiled through ignorance and fraud, nor be liable to have its price enhanced by trade dealers.* All of these indications have been fully met in the preparation which I have described.

The object I desire to attain is to insure a slow action of the gastric juice, or of the excess of acid in the stomach upon the casein of the milk, and this object I attain under all circumstances. Should a slight diarrhœa occur, or a little casein be vomited (a rare accident, to be sure), or casein occur in the stools, then all that is necessary is to diminish the proportion of milk. It may sometimes be necessary, though very seldom, to withdraw the milk entirely for a time, but only in cases of real illness. If the physician or attendants have properly apportioned the ingredients of the mixture, we may rest assured that the child's digestion and assimilation will be regular and normal. Infants that are partly nourished at the breast almost invariably thrive well with the addition of my mixture. Children, from their fourth or fifth month and upward, may often be fed with it exclusively, and not unfrequently nothing else is given from the day of the birth. I can positively affirm that in all these cases assimilation and increase in weight have proceeded quite normally. Altogether, the brief form in which I laid down the above principles, years ago, and in which they have been published year after year by the New York Health Board (See Infant Diet, 2d Ed., 1876, p. 118) for the benefit of the general public, rich and poor, may still be found satisfactory. They read as follows :

I. *About Nursing Babies.*

Overfeeding does more harm than anything else. Nurse a baby of a month or two, every two or three hours.

Nurse a baby of six months and over, five times in twenty-four hours, and no more.

When a baby gets thirsty in the meantime, give it a drink of water or barley-water. No sugar. In hot weather—but in the hottest days only—mix a few drops of whiskey with either water or food, the whiskey not to exceed a teaspoonful in twenty-four hours.

II. *About Feeding Babies.*

Boil a teaspoonful of powdered barley (grind it in a coffee-grinder) and a gill of water, with a little salt, for fifteen minutes; strain it, and mix it with half as much boiled milk and a lump of white sugar. Give it lukewarm, through a nursing-bottle.

Keep bottle and mouth-piece in a bowl of water when not in use.

Babies of five or six months, half barley-water and half boiled milk, with salt and white sugar.

Older babies, more milk in proportion.

When babies are very costive, use oatmeal instead of barley. Cook and strain.

When your breast-milk is half enough, change off between breast-milk and food.

In hot summer weather, try the food with a small strip of blue litmus-paper. If the blue paper turns red, either make a fresh mess, or add a small pinch of baking-soda to the food.

Infants of six months may have beef-tea or beef-soup once a day, by itself, or mixed with the other food.

Babies of ten or twelve months may have a crust of bread and a piece of rare beef to suck.

No child under two years ought to eat at your table. Give no candies; in fact, nothing that is not contained in these rules, without a doctor's orders.

Care of the Teeth.

When should attention be first directed to the care of the infant's teeth?

A lioness in the Zoological Gardens, in London, several times had cubs with cleft palates. Afterward, having been fed during a subsequent pregnancy, not only, as heretofore, with meat from which the bone had been removed, but with bone and meat together, she gave birth to a cub with normal buccal cavity (Berl. kl. Woch., 1875, p. 668). By analogy this case offers a wide range of scientific inquiry. If a simple change in the food during gestation, other conditions remaining unaltered, can bring about so important a result, we must infer that the state of pregnancy has a very important bearing upon the development of the osseous and dental systems. Common hereditary influences, of course, play an important part. The entire osseous system of the parents is regenerated in the offspring. Acquired diseases, such as syphilis, in the parents not only cast their shadows upon the development of the permanent teeth, as Hutchinson claims, but, as I have often observed, affect the temporary teeth as well. Congenital traits, constitutional diseases of all kinds, manifest themselves in the color, structure, thickness, and hardness of the teeth, though the subdivision and classification of the anomalies be frequently carried to excess. Rudolph declares transparent teeth to be rhachitic. Duval regards bluish-white teeth as rhachitic; semi-transparent teeth as "herpetic"; semi-transparent and milk-white teeth as scrofulous and tuberculous. Usually, however, such anomalies are the result of early derangements of health, at a time when the enamel is in process of formation. It has been stated that acute inflammatory diseases leave furrows in the young teeth, and acute exanthemata, such as variola, give rise to indentations. Rhachitis is indeed often associated with thinning of the enamel; but when the process advances somewhat slowly eburnean hardening takes place the same as in bone. Then the teeth of those formerly rhachitic are hard, solid, dense, and yellowish white ; but this yellowish white color is uniform. Where isolated white spots appear, scattered here and there over the teeth, a local trauma is to be inferred, in consequence of which a deposit of carbonate of lime has taken place. Where yellowish and whitish spots alternate with each other, it is the result of long-disturbed health. Not unfrequently it is possible to infer antecedent diseases from the teeth, in the same manner as we may infer a severe disease of nutrition in adults from certain appearances of the nails of the fingers and toes (so long as the nails have not yet been entirely regenerated). Furrows upon the incisors and bicuspids imply a severe illness during the first half of the second year. Furrows on the molars imply such an attack during the fourth or fifth year. The breadth of the furrow is dependent upon the duration of the illness, and different furrows of varying depths indicate separate attacks (Nessel).

From what has now been said, it follows that the normal development of the milk-teeth is dependent, in the first place, upon the condition of the mother during the period of her gestation, and, in the second place, upon the nutrition and health of the child. Hence the care of the milk-teeth should begin before birth, and, as we shall see later, the care of the permanent teeth must begin during the earliest years of life. The teeth of young animals are comparatively very soft and the enamel thin. Hence they are much more liable to injury than the teeth of adults. Portions of the food, taken by the child at frequent intervals, or now and then vomited, may collect in the mouth and undergo fermentation, with the production of acid. Aphthous sores are common in the mouth in very young children, and diphtheritic deposits in those a little older. Acid is produced in the stomach, with acid eructations and acid stools. The young teeth are constantly flooded with the copiously secreted saliva. Teeth and saliva mutually react upon one another. The saliva cannot remain healthy if the teeth are carious and covered with bacteria, nor can the teeth long remain sound with sour saliva. Thus bad teeth, sour saliva, and sour stomach may become a *circulus vitiosus.*

The main requirement in the care of the teeth lies in scrupulously cleansing the mouth. Occasionally it should be washed out with very dilute alkaline solutions, for which purpose borax may be used. Strongly alkaline washes or alkaline tooth-powders tend to do harm by abstracting the lime from the teeth. Another requirement is proper food. What that should be I have endeavored to indicate in another place. A bad stomach is incompatible with good teeth.

Now, is sugar hurtful to the teeth, or has it no effect upon them? Can frequent indulgence in sugar cause caries? When the teeth are much decayed, immoderate indulgence in sugar is often alleged as the chief cause. Sugar is present in all children's food; so the question can concern only its excessive use. The enamel of the teeth may be kept for weeks in a glass of water in which sugar has undergone fermentation without any effect upon it. Can it be otherwise in the mouth? Does the circumstance of the continual passage of air through the mouth cause a difference in the action? Will the effect of sugar account for the fact that the outer surfaces of the teeth are usually the part first affected, or is this the result of slight injuries received from without? Reference has been made to the fact that the plantation negroes, who are constantly chewing sugar-cane, have splendid teeth. But the sugar-juice of the cane is not the same thing as the lime-refined sugar of commerce. Much of the sugar consumed in confectionery and the candies of all sorts adheres more tenaciously to the mouth than simple sugar, and is also adulterated with other substances, which make it more suspicious. But, however this may be, whether any direct and local injurious action can be shown to pertain to sugar as such or not, the inordinate indulgence of confectionery must impair digestion, and thereby become injurious to the teeth. I have seen chronic gastric catarrh precede caries of the teeth and coexist with it too often not to be certain of their intimate relation to each other. The production of acid will render the saliva sour and give rise to a copious development of bacteria, thus leading to caries.

How easily a moderate amount of acidity may become hurtful to the teeth is well seen in the effect of improper indulgence in the juices of fruits. We should seek to mitigate their injurious effect by giving bread or water at the same time, and by afterward carefully cleansing the teeth.

When it is probable that fermentation is taking place in the mouth, the indication is to stop the use of nursing-bottles, sugar-teats, etc., concerning which I had something to say in another place. Without doubt, fermentation in the mouth aids in the crumbling of the teeth, in producing the subsequent indigestion, and in causing the defective articulation which betrays itself in the pronunciation of the consonants d, t, e, s, and st, which, once having become a habit, is not overcome, even after the development of the permanent teeth.

Therefore the care of the child's teeth is mainly preventive. Yet the list of preventive measures would be far from complete, were I not to mention the danger arising from incising the gums, whenever the teeth are slow in coming, an operation that is very commonly resorted to if the child happens to be suffering from some affection not properly recognized. We are all aware that the gums seldom require or justify an incision, whether for inflammation or for unusual thickness or hardness. And yet we know that every ill, whether of head, body, or limb, according to popular nosology, is attributed to teething, and is supposed to furnish a sufficient pretext for the "simple and safe" operation. The literature of the subject, before any diagnoses were made of children's diseases, had grown to formidable proportions. I made a collective report on it myself some years ago.[1] I shall, therefore, confine myself to simply referring to the danger to which the milk-teeth are exposed from external injuries while, though yet concealed, they lie quite near the surface. The injury once having been inflicted, the decay of the tooth is a necessary consequence. This is conceded even by J. Foster-Flagg, who lately not only recommended incisions and scarifications, but insisted upon very free incisions, sometimes crucial and sometimes curved, so as to extend entirely around the tooth. He even gives drawings of these incisions.[2]

When the teeth are healthy, some strict measures of precaution should be taken. These measures will vary somewhat, depending upon the age of the child, inasmuch as children several years old are able to carry out many of the regulations for themselves. After every meal the mouth should be rinsed out with pure water. The same should be done after eating fruit, or after taking medicines or mineral-waters containing iron or tannin. The only addition to the mouth-wash should be alcohol. In exceptional cases, as where the gums and mucous membrane are liable to become spongy and relaxed, very dilute alkaline solutions may be used; concerning strong solutions I have already expressed a caution. When a brush is used for cleansing the teeth (a coarse cloth is better), this should be soft, and should be used not only in a horizontal direction, but also vertically, so as to make sure that no particles of food remain lodged between the teeth. Tooth-powders that contain wood, coal, or other hard substances had better be avoided; and the same with regard to all soaps [see above], with the exception of the sapo medicatus, in which the caustic soda has been completely neutralized. Patent preparations should not be used, for obvious reasons. Any sudden change of temperature in the food must be carefully avoided. Even water of the ordinary temperature must not be too freely drunk with a warm meal. The custom of drinking ice-water, common in the large cities of America, is the most pernicious enemy of the teeth. Under the sudden change of temperature they are liable to crack.

Care of diseased teeth.—With regard to carious milk-teeth, a few simple rules are applicable, of which the best is, whenever the case is at all serious, to consult a competent dentist. It is certainly better to have a tooth filled than to lose it entirely, but it is better to lose it than that its neighbor should become affected by contiguity. In general, milk-teeth

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[1] Dentition and its Derangements, New York, 1862.

[2] Dental Cosmos, Feb.-March, 1873.

should not be extracted till it is absolutely necessary; otherwise the alveolar border sinks away, the jaw does not develop properly, and insufficient room is left for the permanent teeth. These appear in the following order: the middle lower incisors in the sixth year, the middle upper in the seventh, the lateral upper and lower incisors in the eighth, the upper and lower two bicuspids from the ninth to the tenth, the canines from the tenth to the eleventh, the first molars from the eleventh to the twelfth, and the second molars from the twelfth to the thirteenth. When these teeth are robbed of their natural space they are very apt to grow irregularly, often in a double row.

The germs of the permanent teeth are formed at the same time that the temporary teeth are developed, though they do not become ossified before the sixth year. As they gradually become larger, the blood-vessels of the bony partitions, and those supplied to the roots of the deciduous teeth, waste away, the nerves disappear, and the roots atrophy. The partition between the milk-tooth and the sac of the permanent tooth gradually becomes thinner. If the milk-teeth, especially the canines, are extracted prematurely, the permanent teeth are extremely liable to injury, as they lie embedded between the roots of the milk-teeth. The harm done in this way is often greater than that caused by the delayed detachment of the temporary teeth. This latter, however, may act injuriously upon the permanent teeth, affecting their beauty, shape, or number, and under such circumstances the advice of a dentist becomes desirable. There is but one event which imperatively demands the early extraction of a milk-tooth, and that is periostitis, or osteitis of the jaw, due to inflammation of the tooth-root.

So far as the period of the second dentition is concerned, I have nothing to add, with the exception of a caution to my younger colleagues not to accept too implicitly all that has been written and said concerning the frequency of dentition diseases. I have already said that the alleged relation between teething and disease in the first dentition is, to say the least, a very doubtful one; likewise in the second dentition; for if we eliminate all the false and imperfect diagnoses, we shall find this relation between it and the numerous diseases of childhood equally dubious.

Age of Schooling.[1]

The period of life in which children ought to be sent to school, or, rather, the age which allows of additional physical efforts and intellectual labor, depends greatly on individual development. Still there are landmarks which positively indicate the minimum of years required for undergoing unwonted strain. The functions of all the organs depend on their

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[1] This brief chapter may find a place here, though not referring to infancy proper. In my treatment of the subject of the hygiene of the infant body I have endeavored to base my views and recommendations upon anatomical and physiological data; and so here I will endeavor to find accurate scientific indications for the first artificial food of the mind.

anatomical, chemical, and physical development. Thus cerebral action relies to a great extent on fat and phosphorus in the brain substance. In the adult they are mainly found in the white substance of the cerebrum; in the fœtus and infant, however, in the medulla oblongata. Thus it is that the functions of the latter predominate at an early age. Of equal importance is the percentage of water contained in that organ. Its prevalence is in an inverse proportion to normal labor. The more water, the less function, and *vice versa.* Now, the medulla oblongata contains, in the infant, the smallest percentage of water (84.38), and possesses functional superiority. The high percentages of 86.77 in the white, and of 87.76 in the gray substance of the brain of the nursling correspond with the inferior qualities of these parts of the nerve-centres. The increasing percentage of water in the brain of old age, as compared with that of the adult, is the anatomical basis of the "second childhood" (Weissbach).

The differences between the gray and white cerebral substances are but trifling in the very young; the brain is soft, uniform, grayish, its ventricles smooth, the convolutions not variegated. In more advanced age those differences are well marked: the brain is harder, the ventricles more irregular, the convolutions more numerous and various. With these differences correspond the more elaborate functions and capacities for labor.

In the child the peripheric nerves are comparatively larger than the centres; the sympathetic ganglia being the only exception to this rule. The spinal cord predominates over the brain, the centres of motion and circulation in the anterior horns over those of sensation; therefore we find more vascular and reflex function, and less intellectual capacity. The former are direct outgrowths of early and complete development; the latter requires time for growth.

The organs, moreover, do not develop uniformly in all their parts. It takes time before the several parts assume their normal proportion to each other. Originally the occipital cavity amounts to 5, the parietal portions to 81.11, the frontal portion to 13.89, per cent. of the whole capacity of the cranium. The first grows very fast, the second slowly, the third but very little. The increase in size or weight is by no means any more regular. The cerebellum of the new-born (25 grms.) weighs 6.7 per cent. of the weight of the brain; at the age of two months it weighs 9.1; at ten or fifteen years, 12 or 13; in the adult, from 12 to 14. Thus a nearly normal proportion is developed no sooner than at the age of ten or over.

Rapid growth in the first few years is the rule for the totality of the body, and for its several parts; its ratio is not the same, but shows a remarkable resemblance to that which holds good in a great many organs or regions. Schadow states the length of the newly-born to be 18 inches; that of the adult 66. The increase amounts to 10 inches in the first year, 4 in the second, 4 in the third, 3 in the fourth, 3 in the fifth, 2 in the sixth, 1 each in the seventh, eighth, ninth, and tenth years. Thus the retardation commences with the *seventh year.*

The relation of the upper portion of the trunk (chest) to the lower is

1 : 2 in the newly-born ; 1 : 1.618 in the adult. This normal proportion is attained with the *eighth year*.

The lumbar portion grows mainly until the *ninth year* is reached; then again between the twelfth and fifteenth, about the time of puberty. Surely it ought to be moderately developed before children are kept for a long time in a sitting posture. About the same time, between the *seventh and ninth years*, the growth of the lower extremities and the whole body is retarded.

The relation of the height of the cranium to the face is 1 : 1 in the newly-born, 1 : .618 in the adult. This stationary proportion is attained about the *eighth year*. About the fifth and sixth years the base of the brain grows rapidly, and the frontal bone extends forward and upward. The anterior portion of the brain grows considerably; but the white substance and large ganglia still preponderate. Therefore reception and retention are the main cerebral qualities. At that time memory only ought to be trained; complicated intellectual labor ought not to be enforced before the *seventh or eighth year*, in conformity with the above anatomical data, which show a certain amount of consolidation—and interrupted increase—of all the organs of the body.

This result of anatomical and physiological facts corresponds fully with the demand of Friedrich Froebel, whose experience and intuition both led him to postulate the eighth year as the period in life in which children were to be sent to school regularly. Until that time they are to be entertained and gradually developed in the *Kindergarten*. Here their activity is regulated, their attention exercised, and their muscles invigorated. Both imagination and memory are taxed to a slight degree only. With increasing years, the young, gray substance becoming more and more developed, their thinking powers are gradually evolved. As soon as there is a sufficient anatomical basis for them, it will not do to neglect any possibility. The secret of a thorough education lies in the uniform development of all powers. To develop one at the expense of the others is apt to cripple all. In the same manner as the apparently simple muscular action of standing in an erect posture is fatiguing and exhausting when compared with the more complicated labor of walking, the exertion or over-exertion of one mental faculty over the rest injures all, either by direct exhaustion, or by gross neglect of the rest. The body is a cosmos—a republican world in itself—the separate parts, small and large, owing allegiance and support to each other. Exercising one single faculty is a hard and thankless task. Learning by heart is not understanding; cramming is not knowing. Our school-books, with their questions and answers, and with no pretension to practise thinking, exhaust our children, by exercising one function only, while neglecting to evolve their reflection. What has been learned by heart, without being understood and reflected upon, is soon forgotten; meanwhile the mind has not even been sufficiently trained during childhood and youth to resist in later years the gross empiricism we are suffering from in politics, social life, and religion.

Moreover, the injurious influences of school-life, such as it is at present, take hold of younger children more easily than of those more fully developed. Improper or changing temperature, bad air, dust, contagion, insufficient respiratory action and muscular exercise in general, compression of abdominal viscera, endanger young children very much. Nose-bleeding, headaches, anæmia, and scoliosis, brought on by muscular fatigue through the raising of the writing-arm, by improper chairs, by the resting on one sacro-iliac synchondrosis, date from early years. Exhaustion of the brain, when brought on by too early exercise, will increase the tendency to brain disease, epilepsy, chorea. I know of cases in which fatal meningo-encephalitis was surely brought on by mental overwork. But these are subjects which will be treated of in another part of this work.

The time I recommended above as the proper one for sending children to school, is, moreover, that in which morbility and mortality are no longer great. Contagious diseases and affections of the nerve-centres are no longer frequent about the eighth year. The excessive mortality of infancy and childhood is exhausted about the sixth year. Of 100 deaths in one year in New York city, 29.63 occurred in the first; 10.03 in the second; 4.37 in the third; 2.40 in the fourth; 1.64 in the fifth; 3.20 in the sixth—altogether 51.28 in the first six years; in the period between the sixth and eleventh years, but 1.50 per cent. of all deaths take place, exhibiting a great power of resistance on the part of the organism at that age. Even boarding-schools and orphan-asylums show but a slight mortality among children during that period.

No rule, however, is without its exception, and the time for sending a child to school requires individual modifications. There may be reasons for postponing or absolute contraindications to the sending of a child to school at all. Contagious diseases, insufficient cerebral development, epilepsy, chorea, physical debility, some malformations, may render a child's going to school impossible or inadvisable. But the parents ought not to be left to decide independently a question of so much importance to the welfare of those who are to be future citizens. The state or the municipality should exercise the right to prevent children from being sent to school at a premature age.

FOOD AND DRINK.

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FOOD AND DRINK.

THE consideration of the subject of Food and Drink naturally divides itself into two parts—the first of which includes their classification and physiological uses, based upon chemical composition ; and the second, special foods, or alimentary substances, their qualities in the pure, sound, or wholesome state, with their adulterations and inspection.

All intimate knowledge of the operations of food and of the requirements of a wholesome and sufficient diet is necessarily based upon an accurate notion of its chemical composition and physiological action. To the consideration of these we will therefore devote ourselves with some care, describing the various proximate principles which by their union make up the different articles of diet, both animal and vegetable, their office in force or tissue production, and, as far as possible, their course through the economy; then the articles of the so-called Accessory Diet (alcohol, tobacco, tea, coffee, etc.) will be considered, and the physiological action peculiar to them especially indicated. This will be followed by the argument showing the necessity of a mixed food, in which will be pointed out the derangements which follow the use of an exclusive or restricted diet, and the modifications demanded by differences in temperature and climate. Then will be considered the effects of cooking upon food, the true position of soups, and beef-teas, and essences, so called; also the proper daily amount of food, as determined by experience and experiment, for different occupations and surroundings, with the dietaries of armies and navies. Finally, the most important diseases caused by use of deficient, excessive, diseased or unwholesome food, so far as untouched under the argument for the necessity of a proper mixed diet, will obtain a place in our chapter.

The subject of special foods, their adulteration and inspection, will form the subject of another chapter, by a different writer.

In food are included all substances which, after ingestion, contribute to the structural, chemical, and functional integrity of the organism, whether they be directly converted into its tissues, contribute by their oxidation to its heat and other forces, or simply furnish conditions favorable to these operations. According to such definition, water and other inorganic substances which contribute in the latter way, by facilitating solution, osmosis ("molecular currents"), and tissue metamorphosis, are as truly food as the flesh and vegetable matter which are directly converted into tissue, or serve to produce the forces of the economy. That they are as indispensable, has been abundantly proven by observation and experiment. But this difference in the mode of operation of these two kinds of aliment suggests its division into two classes, the *direct* and the *indirect:* the former including substances directly convertible into the elements of the blood and solid tissues, or contributing to force production; and the latter, substances which influence the phenomena of nutrition in various ways.

According to such a definition, it is evident, also, that what in ordinary language is known as "drink," becomes a subdivision of food, and, as such, the various substances constituting "drink" will be considered in this article.

Classification of Food.

Food is further divided into "alimentary substances" and "alimentary principles." The former include the articles of food as supplied us by nature, as meat, fish, milk, vegetables, etc.; the latter include the definite compounds into which these alimentary substances are resolvable by proximate analysis, as the albuminous principles, oily principles, starchy principles.

Numerous classifications of "alimentary principles" have been at different times suggested, some of which are exceedingly elaborate and proportionately cumbersome. There are two, however, which demand attention, both being recommended by their simplicity, while one will be made the basis of our study of the subject. These are the classifications of Liebig and Prout.

The classification of Liebig divides food into: I. *Organic nitrogenous* or *plastic* elements of nutrition or histogenetic food:—including the albumen, fibrin, casein, musculin, globulin, etc., of eggs, flesh, blood, and milk; gluten or vegetable albumen from the various grains; and legumine, a similar substance, comparable to animal casein, found in peas, beans, lentils, and other leguminous plants. These principles are made up of the elements nitrogen, hydrogen, carbon, oxygen, sulphur, and occasionally phosphorus, combined in different proportions. II. *Non-nitrogenous* or *calorifacient food*—respiratory food, or elements of respiration—composed of carbon, hydrogen, and oxygen only. These include, 1st, the carbohydrates, or substances in which hydrogen and oxygen exist in the proportion to form water (sugars, gums, starches, etc.); and, 2d, hydrocarbons, or fats and oils, with their derivatives and allies. These are composed of carbon and hydrogen in combination with only a small proportion of oxygen. III. *Inorganic principles*, including water and salts.

To the first of these groups Liebig ascribed the exclusive function of *histogenesis* or *tissue formation;* to the second, that of *heat production* solely, by the oxidation throughout the body of the carbon and hydrogen, which enter so largely into the composition of the substances included under it. Liebig erred in the exclusiveness of the function assigned to each of the two kinds of organic food. For it is now well understood that the unceasing and innumerable molecular changes which constitute the nitrogenous metabolism of the body are one of the chief sources of its heat; while the nitrogenized, or albuminoid principles, undergo metamorphosis into fatty and even starch-like substances. Long ago Liebig himself showed that the butter present in the milk of a cow is much greater than can be accounted for by the scanty fat found in the grass or fodder she consumes; and that the wax produced by bees is out of all proportion to the fat contained in their food, which is chiefly sugar. Lawes and Gilbert have also shown that for every 100 parts of fat in the *food* of a fattening pig, 472 parts were stored up as fat during the fattening period. Further examples of this transformation are seen in—1st, the formation of *adipocere*, or the peculiar fatty substance into which the albuminoid tissues of dead bodies are sometimes converted after burial;[1] 2d, the transformation of casein into fat in standing milk; 3d, a similar transformation in the ripening of cheese; 4th, the appearance of stearin in the body, when a stearin-free fat, as palm-oil, is added to albuminous food (Subbotin). These phenomena are independent of the fatty degenerations in which, along with numerous other molecular changes, fat is formed by the breaking up of proteid amalgams.

In the second place, fatty matter undoubtedly plays, in certain situations, the rôle of a "tissue," and as such is indispensable to the integrity of the structure in which it is found. This is the case with muscular tissue, gland-tissue, and brain substance, in all of which fatty matter is essential; and to the formation of the so-called *adipose* tissue it contributes largely.

The *general* uses of these principles are, however, undoubtedly correctly assigned by Liebig, ample proof of which is seen in the well-known large consumption of fat by the inhabitants of frigid zones, and the increased desire for fatty food in those native to temperate climates during a temporary residence in cold latitudes. If, then, this exclusiveness of function assigned by Liebig to the two divisions of organic food be thrown aside, his classification becomes sufficiently accurate, simple, and easily remembered.

Equally simple, however, and more easy of comprehension by all, is a slight modification of the classification of Dr. Prout, which is based upon

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[1] It should be stated that some chemists, as Gay-Lussac, Chevreul, and Berzelius, claimed that adipocere is not the result of the metamorphosis of albuminous matter, but simply represents the fat originally present in the body, and that the nitrogenous tissues have disintegrated and disappeared. This view would seem to be sustained by the statement sometimes made that these bodies are shrunk and flattened; but this is far from the case in an admirable example of an adipocere body in the Museum of the Medical Department of the University of Pennsylvania, which is as rounded in contour as it would be possible to be in health, while, instead of being lighter than a body of corresponding size which had lost its nitrogenous constituents, its weight is at least as great.

the proximate composition of *milk*—the typical form of animal food.[1] The classification, which we will adopt as the basis of our study, divides food into

I.—Direct Aliment.

1. Nitrogenous or albuminous alimentary principles, or proteids.
2. Oleaginous principles—hydrocarbons or fats.
3. Saccharine and amylaceous principles, or amyloids; also called carbohydrates.

II.—Indirect Aliment.

1. Inorganic principles.
2. Certain organic principles.
3. Accessory principles.

I.—Direct Aliment.

Nitrogenous or Albuminous Principles—Proteids.

Under these are included the albumen of eggs, or egg-albumen; the albumen, fibrin, globulin, myosin, syntonin, and other albuminoid principles of animal flesh and blood; the vitellin of the yolk of eggs; the casein and albumen of milk; the gluten, vegetable albumen and fibrin of grains, viz., wheat, rye, corn (maize), and oats; and the legumin or vegetable casein of peas, beans, lentils, and other leguminous plants, together with such albuminoid substances as are contained in the juices of the green and soft parts of edible plants and fruits (cabbage, cauliflower, lettuce, apples, pears, etc.). Here, too, belongs *gelatin*, the peculiar principle produced by boiling the so-called gelatin-producing or connective substances, *i. e.*, connective or areolar tissue, tendon, bone, cartilage, and horn. Notwithstanding the low nutritive value of gelatin, as determined by the French and Dutch Commissions,[2] and confirmed by the experiments of Voit and

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[1] Dr. Prout's classification, as presented in the fourth edition, p. 448, of his treatise "On the Nature and Treatment of Stomach and Renal Diseases," London, 1843, is as follows: *Aqueous*, *saccharine*, *oleaginous*, and *albuminous*. The inorganic elements of food are only alluded to by him when treating, p. 479, of what he describes as *secondary* assimilation, or that which takes place subsequent to sanguification, including also destructive assimilation. These "mineral incidental principles of organized beings," he says, may, "under certain extraordinary circumstances," be generated "during the vital processes," but ordinarily "such elements are chiefly derived *ab externo*, in conjunction with the alimentary principles." In substituting the term *inorganic* for *aqueous*, we include the latter substances, while the additional importance assigned by modern physiology to other inorganic food is also acknowledged. The modification of Prout's classification, adopted by Dr. Carpenter in his edition of 1855 and previous ones, and which consisted in the addition of a group of gelatinous food to the other divisions of Prout, is dropped in the seventh and later editions, where he practically returns to the original classification of Prout.

[2] Report of the French Gelatin Commission in the Comp. Rend., Tome XIII., p. 254, Août, 1841, and the Amsterdam Com. in Heb. Instit., No. 2, 1843, and Gazette Médicale, Mars 16, 1844.

Bischoff,[1] its proper position is among the nitrogenous principles of food. The term *chondrin* is applied to the gelatinous principle produced by boiling cartilage.

Albumen.—Albumen may be considered the typical proteid substance. Its percentage composition, according to Hoppe-Seyler,[2] is as follows:

	O.		H.		N.		C.		S.
From	20.9		6.9		15.4		52.7		0.8
to	23.5	to	7.3	to	16.5	to	54.5	to	2.0

which may serve for that of all the proteids.

Notwithstanding their similarity of composition, there are some differences in the albumens derived from different sources, which justify a separate consideration. Thus we have, first, *native albumens* and *derived albumens*, or *albuminates.* By the former are meant albumens in their natural condition in the fluids and solids of the body. They are soluble in water, not precipitated by dilute acids, by carbonates of the alkalies, or by sodium chloride. They coagulate at a temperature of 158° F. (70° C.), and when dried at a temperature of 104° F. (40° C.) a pale yellow, friable, tasteless, inodorous mass results. Albumens are generally intimately united with a small amount of saline matter and also of fat.

I. Of *native albumens* there are two, *egg-albumen* and *serum-albumen.*

1. *Egg-albumen* is familiar to all in its viscid, yellowish, transparent state, known as the white of egg. It is precipitated without coagulation by excess of strong alcohol; and at first the precipitate may be redissolved, but by continued action of the alcohol the albumen is coagulated and cannot be redissolved. It is coagulated by strong acids, as nitric, and by ether; and precipitated, but not coagulated, by mercuric chloride, silver nitrate, and lead acetate. Strong acetic acid and strong caustic potash when added to a concentrated solution convert it into a transparent jelly.

2. *Serum-albumen* is found in blood-serum, lymph, chyle, milk, transudations from the blood, and many pathological fluids, among which is albuminous urine. Although similar to egg-albumen, it differs from it in these respects:—it is not coagulated by ether or readily precipitated by strong hydrochloric acid, while the precipitate finally obtained by the latter is redissolved on the addition of more acid; finally, precipitated or coagulated serum-albumen is soluble in strong nitric acid, egg-albumen not.

II. Of *derived albumens* there are also two, *acid-albumen* and *alkali-albumen.*

1. *Acid-albumen* is produced by the action of a dilute or strong acid upon a native albumen in solution, be it serum- or egg-albumen. Its properties are thus completely altered, but most striking are these: its solution is no longer coagulated by heat, but, on neutralization, all of the albumen is precipitated; it is readily soluble in dilute acids or alkalis, *and these*

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[1] Gesetze der Ernährung, 1860, p. 215.

[2] Handbuch der phys., path., chem. Anal., p. 223.

solutions are not coagulated by boiling. When *suspended* in an undissolved state in water, and heated to 158° F. (70° C.), it is coagulated, and cannot then be distinguished from coagulated serum-albumen.

2. *Alkali-albumen* is produced by the action of a dilute or strong alkali upon serum- or egg-albumen or washed muscle. The product thus obtained, like acid-albumen, is not coagulable by heat, and like it is precipitated on neutralization; and the precipitate, quite insoluble in water and neutral sodium chloride solutions, is easily soluble in weak acids or alkalis.

A similar result is therefore produced by the action of acid or alkali upon a native albumen. There are still, however, differences. Thus, acid-albumen contains sulphur; alkali-albumen does not. Alkali-albumen is not precipitated when its alkaline solutions are neutralized in the presence of alkaline phosphates; the *acid* solutions are precipitated when neutralized under these circumstances. Both alkali- and acid-albumen are precipitated with difficulty from their acid or alkaline solutions by alcohol, but the neutralization precipitate becomes coagulated under the prolonged action of alcohol. Dr. Foster prefers to regard acid- and alkali-albumen as acid and alkali compounds of the neutralization precipitate, since there is reason to believe that, when the precipitate is dissolved in either an acid or an alkali, it enters into combination with them. The neutralization precipitate, which is, itself, neither acid- nor alkali-albumen, but may become either, may be considered an albuminate.[1]

Fibrin.—It is now generally recognized that fibrin as such is not present in the living blood, one of the constituents of which it was so long acknowledged to be. The researches of A. Schmidt[2] have shown that it is the result of the interaction between two substances contained in the blood, *fibrinogen* and *fibrino-plastin* or paraglobulin, in the presence of a third, *fibrin-ferment.* The most recent researches of Schmidt show that, while the fibrinogen is a normal constituent of the blood-plasma, fibrino-plastin and fibrin-ferment are both derived from the *colorless* corpuscles. It is only at the death and disintegration of the latter that the fibrino-plastin and fibrin-ferment are liberated, and produce their effect upon fibrinogen, the result of which is fibrin.

Fibrin thus formed is a fibrillated proteid, containing the same elements as albumen, but a larger amount of sulphur.

Globulin.—Globulin is the albuminoid constituent of the fluid part of the red blood-discs, in which it is united with hæmatin, forming hæmoglobin. It also exists in the crystalline lens of the eye. It differs from albumen in not being soluble in distilled water, requiring, to effect this, the presence of a small quantity of a neutral saline solution, as of sodium chlorin. It is also soluble in dilute acids and alkalis, by which it is converted into acid- and alkali-albumen respectively.

Myosin.—This is the proteid constituent of dead muscle. In its moist

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[1] Foster: Physiology, 1st ed., London, 1877, p. 500.

[2] Schmidt: Pflüger's Arch., vi., 1872, p. 413; xi., 1875, pp. 291 and 515; xiii., pp. 93 and 146.

state it is a gelatinous, elastic mass; when dry, it is brittle and semi-transparent. It is soluble in dilute saline solutions, as of sodium chloride, whence it is precipitated by further dilution or adding an excess of the same chloride. In such solutions it is also coagulated by boiling, and is precipitated by the prolonged action of alcohol. It is described as intermediate between globulin and fibrin.

Syntonin is simply the acid-albumen of myosin, into which the latter is converted by the action of dilute acids, while it is converted into alkali-albumen by the action of dilute alkalis. Syntonin is obtained by treating finely chopped muscle, whence the soluble albumens have been removed, by repeated washing with dilute hydrochloric acid. This dissolves most of the muscle. The syntonin (acid-albumen) thus obtained is in no way distinguishable from the acid-albumen prepared from egg- or serum-albumen.

Vitellin.—This is the modified albumen contained in the yolk of eggs, where it is intimately united with a complex substance known as lecithin, from which, indeed, it cannot be freed without coagulation and consequent alteration. The altered product thus obtained is a white granular body, insoluble in water, but very soluble in dilute sodium chloride solutions. It is not again precipitated from such solution by saturation, as is myosin. When pure, it contains .75 of one per cent. of sulphur, but no phosphorus. It is also converted into acid- or alkali-albumen by the respective action of dilute acids and alkalis.

Casein.—Casein is the proteid of milk, and is the chief constituent of cheese. Freed from fat and moist, it is friable and opaque white. In its reactions it is similar to alkali-albumen, being soluble in dilute acids and alkalis, and reprecipitated on neutralization; though, if sodium phosphate is present, as in milk, much acid is required to precipitate it. It differs from artificially prepared alkali-albumen in yielding a sulphide of potassium when heated with caustic potash; and when digested in artificial gastric juice, it furnishes a body containing phosphorus, whereas the alkali-albumen made from white of egg contains none. Casein differs from fibrin in not coagulating spontaneously, and from albumen in not coagulating by heat. It is thrown down by organic acids which do not precipitate albumen. In addition to the four elements, carbon, oxygen, hydrogen, and nitrogen, it contains sulphur, but there is some uncertainty as to its exact chemical composition. It unites readily with phosphate of lime, and is remarkable for the tenacity with which it retains a large quantity of that substance.

It is prepared by Hoppe-Seyler's method, as follows: Dilute milk with several times its bulk of water; add, drop by drop, dilute acetic acid until a precipitate is obtained; filter and wash the coagulum with water, alcohol, and ether. Magnesium sulphate added to saturation also precipitates casein from milk.[1]

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[1] Gorup-Bessanez, Lehrbuch der physiologischen Chemie, 1874, p. 125; also Foster, op. cit., p. 501.

Vegetable albumen and fibrin.—Vegetable albumen is contained in wheat and other cereals; also in the juices of most vegetables, as turnips, cabbage, cauliflower, carrots, lettuce, etc., whence it may be precipitated by heat. It is also found associated with vegetable casein in the oil-containing seeds, as almonds, walnuts, hickory-nuts, etc.

Vegetable *albumen* is that portion of flour soluble in water and precipitable from its solution by heat. Its proportion is not large.

Vegetable *fibrin* remains behind when flour is washed with a stream of water for the extraction of gluten. The albumen, starch, mucilage, sugar, and some other soluble matters, are carried away with the water, and a tenacious mass is left, known as *crude gluten.* This is the substance which results when flour is kneaded with water. This *crude gluten*, which makes up 10 to 35 per cent. of wheat, but is sparsely present in other grains, is a complex body, composed of vegetable fibrin, casein, and *pure gluten.* By the action of boiling alcohol the *pure* gluten and casein are dissolved out, and the *vegetable fibrin remains.* Vegetable fibrin also exists in the juice of the grape and most vegetables. Of the two substances, gluten and vegetable fibrin, which make up the bulk of the nitrogenous portion of the wheat-grain, gluten preponderates in the central farinaceous portion, and the vegetable fibrin in the exterior.

Vegetable casein or *legumin.*—Vegetable casein is contained in peas, beans, lentils, and other leguminous seeds. It also exists with casein in the almond, walnut, and other oil-containing seeds.

Gelatin and *chondrin.*—The special sources of these have already been sufficiently referred to (p. 148). They are derived only from animal tissues, the *jelly of fruits* being something very different. The latter contains the three elements only, carbon, hydrogen, and oxygen, while gelatin contains, in addition to these, nitrogen and also sulphur.

The striking peculiarity of these substances is the gelatinization of their watery solutions on cooling, resulting in the formation of the peculiar transparent "trembling" substance with which all are familiar under the name *calves'-foot jelly.* Gelatin and chondrin also form the basis of most soups.

The course and destination of the albuminous principles.—Whatever the differences in these proteid substances—and it is evident they are not great—or, however varied their sources in the animal and vegetable kingdom, their course when taken as food is one and the same. After ingestion and mastication, when this is required, they are all converted in the stomach, through the agency of the gastric juice and to a certain extent by the pancreatic juice in the small intestine, into *albuminose* or *peptones* and a small but variable quantity of *parapeptones.*

Albuminose or peptone is itself a proteid not differing essentially in chemical composition from the undigested proteids. It differs from acid-albumen in *not* being precipitated from its acid or alkaline solutions by neutralization; and from the other proteids in not being coagulated by heat, nor precipitated by potassium ferrocyanide and acetic acid; *and in being highly diffusible*, passing through animal membranes with the greatest facility. It is soluble in dilute alcohol, but is precipitated by absolute. The second product of digestion of albuminoid substances, *parapeptones*, which is smaller in quantity the more perfect is digestion, is really acid albumen or syntonin, and possesses the same properties.

The albuminose or peptone is absorbed, chiefly by the capillary blood-vessels of the small intestine, and to a very slight extent, if at all, by those of the stomach; thence it passes into those veins, which by their union form the portal vein, by which it is carried through the liver.

Until recently it was supposed that albuminose was the sole product of the digestion of proteids. It is now, however, definitely known that during the pancreatic digestion of these substances there appear, in addition to peptone, two other nitrogenous crystalline principles, leucin and tyrosin, and, as the proportion of these increases, that of peptone diminishes. The proteid substances, therefore, absorbed from the small intestine, include peptone, leucin, and tyrosin.

At this point, however, our precise knowledge of the course and fate of proteids, how far and how they are converted into the tissues of the body, consumed in producing its heat and energy, or thrown off among the excreta as urea, carbonic acid and salts, ceases. Speculation, aided, of course, by chemical analysis of the fluids and secretions of the body as compared with that of the ingesta, aided also by the laws of physics and chemistry applied to the phenomena of the organism, determines our knowledge of these matters. It must be admitted that great strides have recently been made in this direction concurrent with the advances in modern organic chemistry. For this we are indebted to such chemists as Kühne, Hoppe-Seyler, Gorup-Bessanez, Voit, Bischoff, Pettenkofer, and others. But much uncertainty still overhangs the subject, and what is now written may have to be materially changed in the course of future progress. There is good reason to suppose that the peptones are converted into the albumen of the blood very soon after their introduction into that fluid, and that the liver is the probable seat of this conversion. But the precise changes which subsequently occur are not known.

The Uses in the Economy of Albuminous or Proteid Food.

The uses of the nitrogenous elements of food are two: *first,* to build up and maintain the nitrogenous tissues; *second,* the production of force—force being here manifested in the shape of heat and muscular and nervous power. The former is primarily essential, as are essential the materials of the machine, both for its first construction and its repair. But as the amount of material required after such primary construction is completed, is undoubtedly trifling compared with what is consumed for the generation of the force of which it is capable, so with the human organism, the chief use of proteid food is the production of force.

Liebig originally held, and it was long admitted, that the nitrogenous food in all instances was first converted into the nitrogenous tissues of the body, and that, from the wear and tear, and consequent disintegration of these, there resulted, on the one hand, urea, which was excreted with the urine, and, on the other, carbon and hydrogen, which were oxidized. Now the reverse is held. Nitrogenous food does not first pass into nitrogenous tissues; and it is not through their disintegration that the forces of the organism are generated, any more than by the direct consumption of the material of the machine. They result from the oxidation of the carbon and hydrogen as they exist in the various foods; just as the forces of the machine are due to the oxidation of the carbon and hydrogen of its fuel. The chief object, then, of food, and especially of nitrogenous food, is to act as fuel for the production of muscular and nervous force, a certain small amount being also required for the repair of the tissues of the organism, which are slowly consumed, just as the parts of the machine are consumed by its action, and the more rapidly, the more constant and violent its action.

The old view of Liebig, that muscular action is due to the oxidation of muscular tissue, was first effectually opposed by Drs. Fick and Wislicenus, of Zurich, in 1866. These experimenters proved that increased muscular exertion, such as was made in an ascent of the Faulhorn, was not attended by increased urea-elimination,—which is admitted by all to be the measure of nitrogenous excretion. Not only this, but further calculations, made by Fick and Wislicenus, showed that the amount of work performed in this ascent exceeded by one-half in the case of the former, and three-fourths in that of the latter, the amount of force which could possibly be generated by the oxidation of the nitrogen eliminated. Their results have been amply confirmed by the more recent observations of Dr. Parkes, in 1867 and 1871; while Liebig himself, in 1869, admitted that muscular work and urea-elimination bear no relation to each other, and that among the products of muscular disintegration urea is not one.[1] The opposite results, arrived at by Prof. Austin Flint, Jr., in experimental observations on the pedestrian Weston, in 1870 and 1871, are not generally accepted by modern physiologists.

The method and situation in which this force-production takes place must now claim our attention. As early as 1854, Lawes and Gilbert proved that the nitrogen eliminated in the urine varied as that introduced in the food, being increased by a nitrogenous diet, intermediate in a mixed, and reduced to a minimum with non-nitrogenous food. This observation was confirmed by Lehmann, Schmidt, Fick and Weslicenus, Dr. Parkes, and Mr. Mahomed in careful experiments upon himself in 1871.

The great bulk of the urea, then, may be considered as coming from the excess of nitrogenous food ingested over and above that required to repair the waste of the nitrogenous tissues. According to Bidder and Schmidt, Voit, and others, this extra albuminous food enters the blood, and constitutes there an excess, which they term a "floating capital," upon which the tissues may draw for their repair. That which is not re-

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[1] Proceedings of the Royal Bavarian Academy of Sciences, 1869.

quired for such repair is broken up into a urea-moiety and a force-moiety, the former of which is excrementitious, and the latter is used for the production of force in one of two methods to be considered.

There is reason to believe that the formation of urea takes place in the liver, whence it is carried by the blood to the kidneys. In these organs it is removed by the epithelial lining of the uriniferous tubules by a selective power characteristic of all glandular tissues. Meissner and Cyon have shown that urea is always present in large quantity in the liver of mammals ; but in grave organic disease of this organ, in which its function is arrested, as in acute yellow atrophy, urea disappears from the liver as well as from the urine, in which it is replaced by leucin and tyrosin.

According to a second view, ably presented by Foster in his recent Text-Book of Physiology,[1] but regarded by him as probable rather than fully established, this splitting up of the excess of nitrogenous food at least begins in the small intestine. It has already been stated that among the products of the pancreatic digestion of proteid substances in the small intestines, are leucin and tyrosin, and that these substances are carried along with the peptones by the portal vessels to the liver. Now, the larger the amount of nitrogenous food, the larger is the proportion of leucin and tyrosin produced, and the larger the amount of urea eliminated. Again, if leucin and tyrosin are introduced into the alimentary canal, they appear in the urine in the shape of urea. Leucin and tyrosin themselves never appear in the urine in health, but in the grave diseases of the liver alluded to they are found in the urine in large amount, while urea is wanting. There would seem to be good reason to suppose, therefore, that urea is formed in the liver from the leucin and tyrosin which are produced by a chemolysis, in the alimentary canal, of albuminoid substances. These break up into a urea-moiety—leucin and tyrosin—readily converted into urea, and peptone which is promptly changed into the albumen of the blood. The latter, so far as is not required for the repair of the tissues, is again split up into urea and a force-moiety, composed of carbon, hydrogen, and oxygen. In either event the result is the same.

As already stated, this extra albuminous food was termed by Bidder and Schmidt "floating capital," and its metabolism a *luxus consumption*, which, according to their view, takes place wholly in the blood, while, according to the second view, it occurs partly, at least, in the alimentary canal.

Other probable sources of urea are the kreatin, xanthin, hypoxanthin, etc., which are constantly produced in the muscles, and to a less extent in the glands, and which may, in like manner, be converted into urea in the liver, and possibly also in the spleen. This is the probable source of the urea which is always found in the urine, even on a non-nitrogenous diet, and may be referred to the wear and tear of muscle.

Dr. Pavy, in his excellent treatise on "Food and Dietetics," Philadel-

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[1] 1st Edition, 1877, p. 306.

phia, 1874, thus calculates the force which is rendered available by the metabolism of proteids, taking the percentage composition of albumen as:

Carbon	53.5
Hydrogen	7.0
Nitrogen	15.5
Oxygen	22.0
Sulphur	1.6
Phosphorus	.4
	100.00

Supposing, as is not far from the case, that all of the nitrogen of the ingoing albumen escapes under the form of urea, the nitrogen will carry with it a certain amount of the carbon, hydrogen, and oxygen to form the urea. The percentage composition of urea is:

Carbon	20.000
Hydrogen	6.666
Nitrogen	46.667
Oxygen	26.667
	100.000

Now, to give to the 15.5 parts of nitrogen contained in 100 parts of albumen their proper proportion of carbon, hydrogen, and oxygen, to form urea, the albumen must give up 6.64 parts of the first, 2.21 of the second, and 8.85 of the third, leaving 46.86 parts of carbon, 4.79 of hydrogen, and 13.15 of oxygen, in addition to the sulphur and phosphorus for oxidation and force-production.

With regard to the further fate of the 46.86 parts of carbon, 4.79 of hydrogen, and 13.15 of oxygen remaining out of 100 parts of albumen after the removal of urea, the 13.15 parts of oxygen will appropriate 1.64 parts of hydrogen to exhaust its oxidizing capacity to form water, leaving 3.15 parts of hydrogen and 46.86 parts of carbon in a free state for oxidation. These will require for their conversion into carbonic acid and water 150 parts of oxygen; that is, 100 parts of albumen will be capable of consuming this amount of oxygen in undergoing oxidation. This, of course, enters the blood in the act of respiration, and the products of oxidation are carbonic acid and water, which are always increased by muscular activity.

The force or energy thus resulting is manifested in one of two ways: *mechanical labor* and *heat*. The first of these includes muscular action in all its various modes of manifestation, locomotion, respiration, speech, etc. All such mechanical labor, including that of the heart and bowels, the molecular phenomena of the nervous tissues in the activity of thought and mental energy, and the metabolism of secretion, are converted into heat, which is given off from the body by radiation, respiration, perspiration, and the warming of the egesta.[1]

Now, if the force-demands of the organism, in the shape of muscular and nervous energy and heat, are exactly balanced by the force resulting from the oxidation of the carbon and hydrogen of the food, the weight of the body remains the same. If these are insufficient, it emaciates. If, on the other hand, these are more than sufficient, they are stored up in the shape of fat or adipose tissue, which subserves the double purpose of keeping the body warm, and of storing up carbo-hydrogenous material to meet future demands beyond those met by the immediate food-supply. In this manner, as has been frequently stated in this paper, and as has been shown over and over again, by experiment and observation, the body may gain in weight by the use of nitrogenous food alone.

OLEAGINOUS PRINCIPLES OF FOOD—FATS—HYDROCARBONS.

These include the whole category of oils and fats and their derivatives, the so-called *hydrocarbons*, composed of carbon, hydrogen, and a small proportion of oxygen. They are therefore non-nitrogenous. The chief are olein, stearin, palmatin, and margarin. Some one or more of these make up the chief bulk of all animal and vegetable fats, including beef- and

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[1] The exact seat in which these changes take place is still undetermined. Voit and others contend that these oxidations take place in the blood, the "blood-" or the "circulating-albumen" being the seat of a direct oxidative metabolism; while Foster (Text-Book of Physiology, 1st ed., p. 317), who has investigated this question closely, claims that they take place in the muscles, admitting, also, that "of the exact nature of the chemical changes we know nothing" (p. 69). Such changes are additional to those resulting in such nitrogenous crystalline bodies as kreatin, etc., which are present in muscle, and may be regarded as the results of the wear and tear of the machine, and not as products of the material consumed in work. By these observers the phenomena of muscular contraction are regarded as "an explosive decomposition of certain parts of the muscular substance," resulting in the production of carbonic and lactic acids, while heat is set free as well as specific muscular energy. This explosion involves the decomposition of some nitrogenous products, which are, however, retained within the tissue and again consumed. Foster says (op. cit., p. 70), "It may be worth while to point out that, during even the most complete repose, muscle is undergoing chemical changes, which, so far as we know, are the same in kind, and only different in degree, from those characteristic of a contraction. Thus, carbonic acid is constantly being produced, and probably lactic acid, both being got rid of as they form, just as they are got rid of in larger quantities during the repose which follows contraction. Supposing the existence of a substance which splits up into these various products, and which we may speak of as the true contractile material, it is evident that this material, being thus constantly used up, must be as constantly repaired. *Thus, a stream of chemical substances may be conceived of as flowing through muscle, the raw material brought by the blood (together with the nitrogenous elements still remaining in the muscle) being gradually converted into true contractile stuff, which as gradually breaks down again, while the muscle is at rest; when a contraction takes place, the decomposition is excessive and violent.*" It will be observed that the explanation presented in the text of the phenomena of nutrition, is based upon Voit's views as to the seat of the oxidations, since it seems to the writer that they afford the simplest explanation of these phenomena.

mutton-suets, butter, the oil of milk, of the yolk of eggs, and the fatty matters of the bile and brain; also the fatty acids, butyric, capric, and caproic; and the vegetable oils, including those contained in corn and oats and other seeds and fruits.

The percentage composition of the principal fats is, carbon, 79; hydrogen, 11; oxygen, 10. The chemical formula is $C_{10}H_{18}O$.

It is evident from the above enumeration that they are contained in both animal and vegetable food.

The chief fats, olein, stearin, margarin, and palmatin (neutral fats), are compounds of a fatty acid, oleic, stearic, margaric, and palmatic, combined with a hypothetical radical called the oxide of lipyl. On decomposition of any one of these fats by contact with alkalis—that is, by saponification—this principle takes up an equivalent of water, and becomes the well-known substance *glycerin*, which, according to the old chemistry, was regarded as a hydrated oxide of lipyl. According to the new nomenclature, it is a *propenyl alcohol*, and its formula is $C_3H_8O_3$.

Stearin is the hardest of the fats. It is solid at ordinary temperatures, and is the chief constituent of fats thus solid; but it exists to a greater or less extent in most, if not all animal, though not in vegetable fats. It melts at a temperature of 145° F. (62–71° C.).

Olein is fluid at ordinary temperatures, being the chief constituent of the fluid fats or *oils*, most of which are derived from the vegetable kingdom, as olive-oil, linseed-oil, etc.; but it is also found in animal fats.

Palmatin is a fat, also solid at ordinary temperatures, melting above 113° F. (45° C.). It is for the most part a vegetable fat, being best made from palm-oil.

Margarin is now believed to be a mixture of olein and stearin. It is intermediate to them in consistency.

The Uses of Fats.

Fats are digested in the small intestine, chiefly by the agency of the pancreatic juice, by which they are emulsified, or reduced to a minute state of subdivision. Thus emulsified, they are absorbed by the lacteals in the villi and carried through the mesentery into the pancreatic duct, and thence into the venous system.

The uses of the fats are two: *first*, force-production (heat and mechanical energy); *second*, the formation of fatty or adipose tissue. First, in the rôle of a force-producer, the process is precisely similar to that in which the force-moiety of nitrogenous food is worked up, by the oxidation of its carbon and hydrogen in the blood. It is, therefore, unnecessary to go into any details farther than to show that for these purposes fats are the most efficient of all the foods.

It has already been shown, in estimating the force-value of nitrogenous food, that after the removal of the elements to form urea, and the deduction of the hydrogen required to convert the remaining oxygen into water, there remained 46.86 parts of carbon and 3.15 of hydrogen free to be oxidized by oxygen supplied in respiration, and that these amounts of carbon and hydrogen would require 150 parts of oxygen to convert them into carbonic acid and water. Now, fat contains 79 parts of carbon, 11 of hydrogen, and 10 of oxygen. The 10 parts of oxygen will take 1.24 parts of the hydrogen to form water, leaving 79 parts of carbon and 9.76 of hydrogen to be oxidized by oxygen from without. The amount required to convert this into carbonic acid and water is 293 parts of oxygen, or *nearly twice as much as* 100 *parts of albumen require.*

There can be no doubt whatever that this is an exact measure of the heat-producing power of fats. And thus we have shown, by calculation, why the natives of frigid climates, as the Esquimaux, Icelanders, etc., consume such enormous quantities of fat as food, and why we ourselves, during the winter season, are enabled to take more fatty food without discomfort than in summer.

This, according to Liebig, was the sole object of fatty food—the production of heat; force being, according to him, due to the disintegration of nitrogenous tissues, into which all nitrogenous food was first converted. But the experiments of Dr. Edward Smith, of Pettenkofer and Voit, with their delicate apparatus for the measurement of carbonic acid, have shown conclusively that the effect of increased muscular exertion is not in increased urea-elimination, as was supposed by Liebig, but in increased carbonic-acid elimination, the measure of carbon oxidation.

The second purpose of fatty food, the formation of adipose tissue, takes place when the amount ingested is more than sufficient to subserve the heat and mechanical force-demands of the economy. Adipose tissue is more or less present in all persons, filling up the interstices, and rounding the outlines of the form, while it is excessive in fat persons. It is also intimately incorporated with the protoplasm of many nitrogenous tissues of the body, in which the condition in which it exists is aptly compared to an amalgam, whence again it is sometimes separated in the well-known pathological phenomenon of fatty metamorphosis. Thus present, it performs the double rôle of maintaining, by its non-conducting properties, the warmth of the body, and of serving the purpose of a store-house of carbon and hydrogen, whence it is absorbed when the amount supplied by the food is insufficient to supply the force-demands of the economy. It is well known that when man and the lower animals are deprived of food, those endure the longest which are fattest.

The same question as to the exact seat of the oxidation, whether in the blood or in the tissues, may also be raised with regard to the hydrocarbonaceous as with regard to proteid food. It has been stated that hydrocarbonaceous matter is intimately commingled with nitrogenous matter in muscular tissue, and it may be in this situation that it is oxidized, or it may be while floating in the blood. The question must, for the present, remain unanswered.

It must not be forgotten, however, that fatty food can only be made available when used in connection with nitrogenous food. An animal fed upon fat alone soon ceases to digest, loses its appetite, and dies of starvation. Fats themselves do not incite metabolism; indeed, they check proteid metabolism, while proteid food increases non-nitrogenous as well as nitrogenous metabolism. Hence, by the use of a pure nitrogenous diet, the fat of the body may be gradually reduced. Advantage of this fact is taken in the Banting system of diet, which has for its object the diminution of the weight of the body, by the use of a pure nitrogenous diet, and the omission of all fats, starches, and sugars.

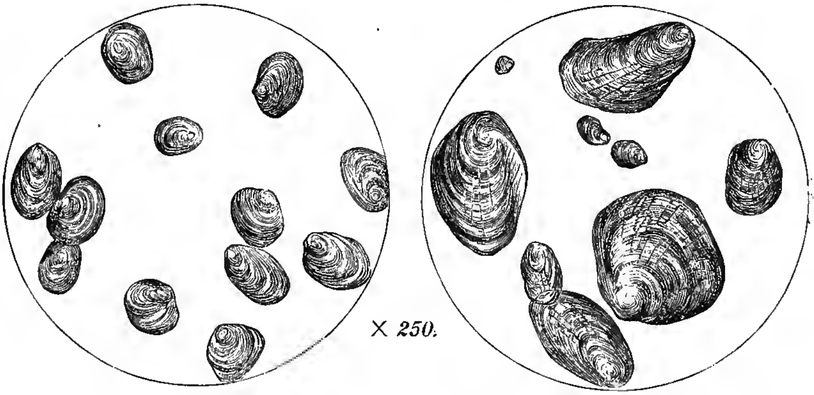
SACCHARINE AND AMYLACEOUS PRINCIPLES—AMYLOIDS.

These include—1st, the starches (of potatoes, rice, sago, tapioca, of the seeds of leguminous plants, of the grains and of the green, succulent parts of vegetables), and dextrin; 2d, the sugars, including cane-, honey-, grape-, and beet-sugars, sugar of milk, liver-sugar, inosite or the sugar of muscle; 3d, the gums and mucilages of fruits and vegetables, cellulose, lignin or woody fibre.

These are also called carbohydrates, being composed of carbon, hydrogen, and oxygen, with the latter two in the proportion to form water. It is evident, also, that their chief source is the vegetable kingdom.

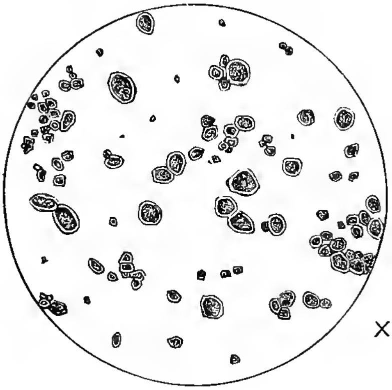
THE STARCHES.

Starch ($C_6H_{10}O_5$) is an ingredient of most edible vegetables and fruits, and makes up a large proportion of the various grains, seeds, and roots which are used as food for men and animals. It exists in the shape of minute granules from $\frac{1}{10000}$ to $\frac{1}{400}$ of an inch in diameter, the largest of which are characterized by their peculiar, laminated, concentric arrangement, with slightly excentric depression or hilum. The granules are decidedly different as derived from different sources. Thus, in the *potato*, their range in size is greatest, covering the limits named above. They are irregularly pear-shaped, and their concentric markings are very dis-

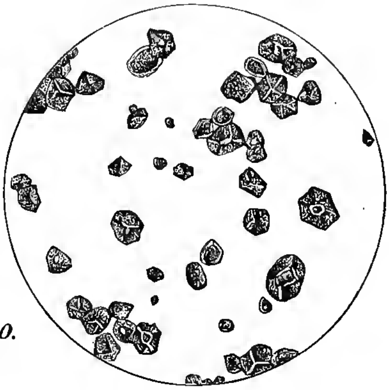


Arrow-root. (See note on page 207.) Potato.

tinct. Those from *arrow-root* are smaller and more uniform in size, ranging, generally, between $\frac{1}{2000}$ and $\frac{1}{500}$ of an inch. They are more oval in shape, and their concentric markings, though distinct, are less so than in the potato; and the hilum sometimes has the shape of a transverse slit.

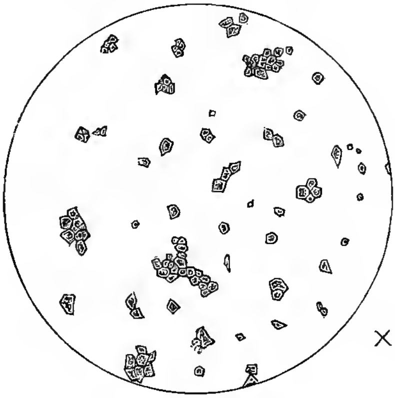


Wheat.

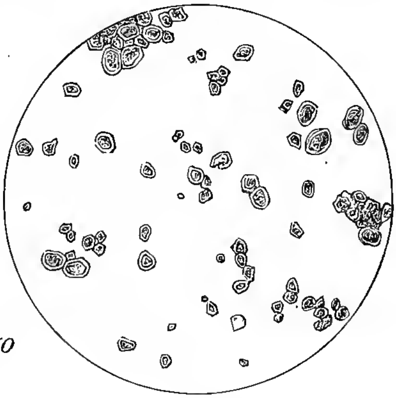


Corn.

The granules of *wheat-starch* are still smaller, from $\frac{1}{10000}$ to $\frac{1}{700}$ of an inch in diameter, nearly circular in outline, often flattened, and very seldom present a hilum. There is no distinct concentric marking. The starch-grains of *indian-corn* are similar, but more distinctive, and instead of the usual hilum, sometimes present a crossed or radiating marking.



Rice.



Oats.

The starch granules of *rice* are very small, the smallest of all commercial starches; being about $\frac{1}{5260}$ of an inch in diameter. They are irregularly polygonal in shape. *Oat-starch* granules are quite variable in size, six measurements by Mr. Geo. Jackson giving a range in diameter of from $\frac{1}{10000}$ to $\frac{1}{1000}$ of an inch. They are triangular and polyhedral, present no evident concentric markings, and by no means always a hilum.

Starch granules are readily recognized by the bright-blue color they promptly strike on the addition of iodine. They are insoluble in cold water; but in hot water they swell up, promptly lose their morphological peculiarities, finally burst and fuse, forming a homogeneous mass, which varies in consistence with the quantity of water present. In this shape starch may still be recognized by the iodine reaction.

Starch, as a food principle, is derived solely from the vegetable kingdom. The chief articles of food which contain it are indian-corn, wheat, rye, oats, rice, potatoes, beans, peas, arrow-root, sago, tapioca. None of them, of course, are purely made up of starch. The following table exhibits the proportion of starch in 100 parts of each of the articles named.

Rice	85.07	Wheat-flour	72.00
Maize	80.92	Iceland moss	44.60
Barley-meal	67.18	Kidney-bean	35.94
Rye-meal	61.07	Peas	32.45
Oatmeal	59.00	Potato	15.70

Starch, in its unchanged state, is a *colloid*, totally incapable of absorption, even in thin mixtures with warm water. In the act of digestion, therefore, it is converted, first, into dextrin, and then into grape-sugar. There are at least two digestive fluids which possess this power—the saliva and pancreatic juice. It is generally thought that starch is too short a time in contact with the saliva during its passage through the mouth to be much influenced by such contact; but, although this is probably true of uncooked starch, yet it is a fact that it is not possible to introduce boiled starch in the mouth and remove it sufficiently soon to avoid the conversion of much of it into grape-sugar. It seems, therefore, not unlikely that in the few minutes during which the starch of cooked articles of food is subjected to the saliva in the act of mastication, a considerable portion is thus converted. It is also probable, however, that the conversion takes place chiefly through the action of the pancreatic juice, after the food has passed from the stomach into the small intestine. Thus converted, the grape-sugar is promptly absorbed by the capillaries of the villi, and passed thence into the portal vein and liver.

Dextrin ($C_6H_{10}O_5$) is a sweet substance, very adhesive in its solutions, identical in composition with starch, whence it is derived by the action of heat, mineral acids, and *diastase*, a ferment which is developed during the germination of barley and other grains. Dextrin does not exist as such in nature, but all starch in its transition into grape-sugar or dextrose first becomes dextrin. Although, artificially, dextrin may be produced and retained as such, it is not likely that in the process of digestion it maintains itself as dextrin for any length of time, but passes quickly into grape-sugar.

THE SUGARS.

Of these there are several, some derived from the animal kingdom, but mainly they are found in the vegetable. Among the *vegetable sugars* are cane-sugar, grape-sugar, beet-sugar, glucose or sugar of starch, and honey. The latter is a mixture of several varieties of sugar collected from the sweet juices of flowering plants, and includes among them cane- and grape-sugar. These are mingled with a small amount of animal matter. Among *animal sugars* are sugar of milk, liver-sugar, and inosite, or muscle-sugar.

Cane sugar ($C_{12}H_{22}O_{11}$) is contained in solution in the juices of the stem, roots, and other parts of various plants, particularly the so-called sugar-cane, which is cultivated for the sugar it contains. It is crystallizable, and is the form of sugar most used as food. Although not a necessary condition of its absorption, cane-sugar is probably almost totally converted into grape-sugar in the alimentary canal previous to absorption. Evidence of this is found in the fact that when cane-sugar is injected into the blood, it is excreted as such by the kidneys; whereas if an excess of sugar is taken into the stomach, it is excreted as grape-sugar. This change in cane-sugar is most likely wrought, partly by the action of the pancreatic juice, and is partly the result of the metabolism always taking place among organic substances in the small intestine. It is well known that the admixture of sugar with decomposing animal matters, outside of the economy, results similarly. Cane-sugar is readily converted into grape-sugar by boiling with a little sulphuric acid. It does not reduce the oxide of copper.

Grape-sugar or *dextrose* ($C_6H_{12}O_6$, H_2O) is contained in the juice of grapes and other fruits, while it is also the form of sugar into which starch and cane-sugar are converted by natural and chemical means. It is the sugar of preserved fruits and jellies used as food. It requires no special preparation to fit it for absorption, but it sometimes undergoes conversion during digestion into lactic acid. This change is perhaps pathological rather than physiological, and probably gives rise to one form of acid-dyspepsia; it is readily accomplished, since grape-sugar has only to lose its water to acquire the same elements in the same relative proportions as lactic acid.

Beetroot-sugar is similar to cane-sugar, except that it is harder and more insoluble than cane-sugar. Large quantities of beautiful white loaf-sugar are made in France from the juice of beet-roots, and its production is now claiming considerable attention in some sections of the United States.

Glucose, it has already been said, is the sugar into which starch is capable of conversion, and is identical with grape-sugar. *Honey*, as has been stated, is a mixture of grape- and cane-sugar with a small amount of organic matter.

Of the *animal sugars*, *sugar of milk*, or lactine, is the best known. Its formula is $C_{12}H_{22}O_{11}$, H_2O. Its name indicates its source—the milk of animals, whence alone it is derived. It is similar to grape-sugar in some of its properties, but is more difficult of solution, and harder.

Liver-sugar (C_6 $H_{12}O_6$ or $C_6H_{10}O_5+H_2O$) is found, after death in the substance of the liver in considerable quantities. It was first discovered by Bernard, in 1853. There is some difference of opinion as to whether sugar exists as such in the living liver. Pavy, MacDonnell, and others deny that it exists during life, as such, but contend that there exists in its stead the amyloid substance, also discovered by Bernard and named by him *glycogen.* It has also been called zoamylin or animal dextrin.[1] This is promptly converted into glycogen by the presence of any dead organic matter; so that immediately after death the conversion takes place. Recent repetitions of the experiments on the subject by Flint, Jr., Lusk, and Dalton, of this country, reaffirm the original position of Bernard, that sugar is produced in the liver during life, independently of the food consumed, although the use of starchy matters and of sugar as food, greatly increases the quantity produced. Still more recently (1877), Dr. Pavy has re-examined the entire question with the aid of improved methods of testing for sugar, and reaffirmed his position. These studies are published in the treatise referred to in the foot-note. That, when present, the sugar is produced in the cells of the liver, and not in the blood, is proved by the fact that the blood of the organ may be thoroughly washed out and subsequently a stream of water passed through until no sugar is longer present; then, after a short time, sugar again makes its appearance in the liver, as may be proved by applying Trommer's test to a decoction of the organ. It also exists, to a slighter degree, in muscle, white blood-corpuscles, the testes, brain, and placenta, while the tissues of the embryo at an early stage contain a large proportion.

Liver-sugar is identical in chemical composition and properties to grape-sugar and glucose.

Inosite, or muscle-sugar, is another sugar usually termed animal, although it is found in very small quantities in animal tissues, and abundantly in vegetables. Its formula is put down as $C_6H_{12}O_6+2H_2O$. It was first discovered by Scherer in heart-muscle; but Cloetta also found it in the lungs, kidneys, spleen, and liver, and Müller in the brain. It also occurs in diabetic urine and that of Bright's disease.

Gum ($C_{12}H_{22}O_{11}$) is familiar to all as the transparent exudation often seen on the bark of trees. It is found, however, in the juices of nearly all plants. When pure, it is tasteless and colorless, and when mixed with water produces an adhesive fluid, or mucilage. It is converted into sugar by boiling with sulphuric acid. It is a colloid substance, of extremely low osmotic position, and therefore necessarily low in nutritive qualities, unless it be converted during digestion into a more diffusible substance, as sugar, as to which there is as yet no evidence.

Cellulose ($C_{18}H_{30}O_{15}$) is the substance forming the basis of the cell-walls, fibres, and vessels of plants. Cotton, linen, and elder-pith are nearly pure cellulose. It is quite insoluble in digestive fluids, and, when taken into the alimentary canal with food, is passed out with the fæces unchanged. It is

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[1] In his recent work, entitled Points connected with Diabetes, London, 1878, Dr. Pavy suggests the name "Bernardin" for this substance, out of consideration to the great physiologist to whom we are indebted for our knowledge of its existence.

soluble in the more powerful chemical agents, as potash and the mineral acids ; and by the action of sulphuric acid and heat it is converted, first, into dextrin, and then into grape-sugar.

Lignin or woody fibre ($C_6H_{10}O_5$) is the chief solid matter deposited within the woody fibre, and is the element which gives it its firmness. It is similar to cellulose in its resistance to the action of the digestive fluids.

Pectin is the basis of vegetable jellies. It is found in most fruits and many vegetables, but in quantity too small to be of much importance as an alimentary principle.

Uses of the Carbohydrates.

It is evident, from the above considerations, that the most important members of this group of carbohydrates reach the circulation in the shape of grape-sugar. The study of their fate, therefore, becomes the study of the fate of grape-sugar after absorption. It has already been stated that an abundance of such sugar is found in the liver after death, that it is even found there when the animal is fed upon a non-nitrogenous diet, but that it is very much increased by the use of amylaceous and saccharine food. It has also been said that, in the living liver, the sugar is not stored up as such, but escapes in the shape of a starch-like substance called by Bernard *glycogen*, into which, according to this experimenter, the saccharine and amylaceous principles must be converted before they become liver-sugar.[1] This glycogen, again, according to Bernard, is being constantly converted into sugar, which is passed into the blood and out of the liver by the hepatic vein. According to Pavy, on the other hand, the glycogen thus resulting is not converted into liver-sugar during life, but is there converted into *fat*, of which it is a preliminary stage intermediate between sugar and fat. Certain it is that animals fed upon saccharine and amylaceous food, together with fatty food, increase the amount of their fat over and above that which could be supplied by the fat alone. On the other hand, we have no proof that sugar can be oxidized in the blood, either in the lungs or systemic capillaries, although this was at one time supposed to be the case. But the view of Bernard, which, to say the least, has not been sufficiently disproved, may still be correct. For, as Dr. Foster says, there may be a certain percentage of sugar necessary to a proper composition of blood. This may be drawn upon by the tissues, and especially muscular tissue, which is known to contain sugar, and which it may require as an essential element of its contractile substance. In either event, the glycogen of the liver may be looked upon as a reserve fund of carbohydrate material, a view which is supported by the analogous migration of starch in the vegetable kingdom. It is well known that the starch of the leaves of the plant, whether having passed through a glucose stage or not, is converted into sugar, carried down to the roots and other parts, where it is again converted into starch. So the grape-sugar, into which the

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[1] It must be remembered that sugar requires only to be dehydrated to be converted into starch, as starch requires but to be hydrated to be converted into sugar.

starchy and saccharine principles are converted before absorption, may be converted in the liver into glycogen, in the shape of which it may be there stored up, and, little by little, reconverted into sugar, passed into the circulation and taken up by the muscular and other tissues which require it.

According to either view, the measure of the ultimate amount of force produced is the same. If the view of Bernard be correct, and the sugar passed into the blood is taken up by the muscles to form their contractile tissue, it is used up, oxidized, in the metabolism of muscular contraction. If Pavy be right in stating that the glycogen of the liver is converted into fat, the force resulting will be represented by the oxidation of the fat; and as only the amount of carbon and hydrogen contained in the carbohydrates can become the carbon and hydrogen of the resulting fat, the force produced will be represented by the oxidation of these elements. But the peculiarity of the carbohydrates is that the hydrogen and oxygen exist in the proportion to form water, so that the carbon alone remains to be oxidized. Hence, the maximum force which can possibly result from the oxidation of the carbohydrates must be considerably less than that from the fats, because in the latter, in addition to the carbon, there remains also some hydrogen to be oxidized.

The following table, from Pavy,[1] will show the relative value, as force-producers, of the carbohydrates, compared with nitrogenous and fatty principles:

	Amount of oxygen required to oxidize 100 parts, as oxidation occurs within the body	Units of heat produced by oxidation of one gramme (15.432 grains), as oxidation occurs within the body.
Grape-sugar	106	3277
Starch	120	3912
Albumen	150	4263
Fat	293	9069

It is scarcely necessary to repeat that experiment and observation have abundantly shown that amyloid substances alone are incapable of sustaining life. Even when mixed with other principles, any excess of them is found to appear in the urine in the shape of grape-sugar.

II.—Indirect Aliment.

Under this head are included substances chiefly inorganic, but including also some organic, which are not chemically changed in their course through the body, but pass out dissolved in the secretions in the same chemical condition and in nearly the same quantities in which they are ingested. They cannot, therefore, be regarded as producers of force. At the same time, many of them become important constituents of various tissues of the body, both solid and fluid. This division includes, also, certain organic substances, which contain a principle, either alone or in

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[1] On Food and Dietetics, Philadelphia, 1874, p. 136.

addition to other alimentary matters, the effect of which is to diminish the wastes of the economy. These substances, although not indispensable as food, are used by so large a proportion of the nations of the earth as to become a most important article of commerce. They have received the name of *accessory food*, or *accessory articles* of diet.

1. *Inorganic Food.*

This is, at least, the most indispensable division of indirect aliment. Under it are included water and watery solutions of certain inorganic principles, viz., sodic and potassic chlorides, sodic, potassic, and calcic phosphate, calcic carbonate, etc., together with iron, sulphur, silica, and other elements entering into the composition of some of the more complex principles of food already considered. These, except water and sodic chlorides, are contained in ordinary articles of food in requisite proportion, and therefore do not, as a rule, require to be especially provided.

The precise mode in which these substances become useful and indispensable is not known. It requires no reasoning to show that water is an absolutely essential article of food. Sodic chloride, or common salt, presents us with one of the most familiar illustrations of an indispensable saline substance, the necessity of which has been over and over again demonstrated. Its importance might be inferred from its well-known solvent properties over albuminous substances, with which we became familiar in our study of these. Experiment has also been brought to bear on this question; and among the best-known results are those of Boussingault, who fed six bullocks with an abundance of nutritious food, but to three of them (lot No. 1) gave also 500 grains of salt per day, while the remainder (lot No. 2) received no salt. "Until the end of March (the experiment began in October) the two lots experimented on did not present any marked difference in their appearance; but, in the course of the following April, this difference became quite manifest, even to an unpractised eye. The lot No. 2 had then been without salt for six months. In the animals of both lots, the skin had a fine and substantial texture, easily stretched and separated from the ribs; but the hair, which was tarnished and disordered in the bullocks of the second lot, was smooth and glistening in those of the first. As the experiment went on, these characters became more marked; and at the beginning of October the animals of lot No. 2, after going without salt for an entire year, presented a rough and tangled hide, with patches here and there where the skin was entirely uncovered. The bullocks of lot No. 1 retained, on the contrary, the ordinary aspect of stall-fed animals. Their vivacity and their frequent attempts at mounting contrasted strongly with the dull and unexcitable aspect presented by the others."[1]

It is also well known that animals will travel long distances in search

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[1] Dalton: Physiology, 5th Ed., Philadelphia, 1871, p. 57, from Chimie Agricole, Paris, 1854, p. 271.

of salt, striking illustration of which is found at the "salt licks" of our Western country. Dr. Letheby[1] has collected many facts bearing on this subject, of which the following are among the more striking: "Among the Gallas, and on the coast of Sierra Leone, brothers will sell their sisters, husbands their wives, and parents their children, for salt. In the district of Accra, on the Gold Coast of Africa, a handful of salt is the most valuable thing on earth after gold, and will purchase a slave or two. Mungo Park tells us that with the Mundingas and Bambaras the use of salt is such a luxury that to say of a man, 'he flavors his food with salt,' is to imply that he is rich, and children will suck a piece of salt as if it were sugar. No stronger mark of respect or affection can be shown in Muscovy than the sending of salt from the tables of the rich to their poorer friends." All of these instinctive demands are decided indices of the position of salt as well as of other similarly constant inorganic matters as food.

One of the effects of salt would seem to be to increase the rapidity of tissue metamorphosis; while the free use of water, both externally and internally, seems likewise to increase the tissue changes in the economy. At least such is the result of Dr. L. Lehmann's[2] observations on hip-baths; from which he concluded that, *first*, they lessen the action of the pulse; *secondly*, that they increase the amount of urine generally, and especially of its water, urea, uric acid, and fixed salts; *thirdly*, that they increase the insensible perspiration; and, *fourthly*, as a consequence of these effects, that they promote the metamorphosis of tissue. And although the observations of Böcker[3] and Lampe failed to confirm Lehmann's results, yet the former are simply negative, and prove nothing to the contrary; while those of Virchow[4] and Wundt[5] tend to confirm them.

From these facts we are justified in concluding that the free use of water, if accompanied by an abundance of nutritious food, would result in the production of a most perfect state of the organism, while its excessive use, especially when attended by insufficient and non-nutritious food, might impair the health of the individual.

In further illustration of the uses of this form of indirect aliment, we may refer to the *alkaline* or *basic sodic phosphate*, and the *acid potassic phosphate*—the former of which is invariably found in the blood, while the latter is the chief constituent of the juice of flesh. As suggested by Dr.

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[1] Letheby: On Food; its Varieties, Chemical Composition, etc., Am. Ed, New York, 1872, p. 80.

[2] Lehmann, Dr. L.: On the Action of Baths, in Archiv des Vereins für gemeinschaft. Arbeit, Band I., S. 515, and Baud II., S. 1.

[3] Böcker: Ueber die Wirkung der Sitz-Bäder, der Brause, und der nassen Einwickelung auf den Ausscheidungsprocess, in Moleschott's Untersuchungen zur Naturlehre, Band VI., Heft 1, 1859. Lampe's observations were published with Böcker's.

[4] Virchow: Physiologische Bemerkungen über das See-Baden, mit besonderer Rücksicht auf Misdroy, in Virchow's Arch. der path. Anat., Band XV., S. 70.

[5] Wundt: Observations on the Influence of the Wet Sheet on Excretion, in Archiv für wissen. Heilk., Baud III., S. 35.

See also a review of the above authors in the British and Foreign Medico-Chirurg. Review, Vol. XXX., 1862.

Letheby,[1] the former is probably concerned in preserving the liquid colloidal condition of albumen and fibrin, and so keeping them from being lost in secretion, while the latter is engaged in an opposite duty in converting the colloidal liquid into the solid tissues of the body. The basic sodic phosphate, like an alkaline carbonate, also possesses the property of absorbing carbonic acid, which it discharges when the blood reaches the lungs, and it thus becomes an important agent in the removal of this acid from the body.

The effect of a diminished supply of phosphoric acid and the phosphates upon the proper firmness of bone, as well as the effect of their administration when the bones are deficient in them, is well known.

2. *Organic Indirect Aliment.*

A second division of indirect aliment includes certain organic acids of animal origin, as lactic acid, acetic acid, derived from both animal and vegetable sources, and the vegetable acids, citric, tartaric and malic. Acetic and lactic acids belong, chemically, to the carbohydrates, but behave differently. The vegetable acids contain oxygen in excess of that required with hydrogen to form water. All of this group, when ingested in the free state, according to Wöhler, pass through the system unchanged, reappearing in the urine. When introduced in combination with alkalis, however, they undergo oxidation, and appear in the urine as carbonates. In consequence of this fact, they are constantly used in medicine to alkalize the urine.

Their importance as food is amply illustrated in the effects of their long absence from dietaries, which is a well-known cause of scurvy, purpura, and other blood dyscrasiæ, while they are among our best remedies for these affections.

Acetic acid ($HC_2H_3O_2$) is contained in the juice of many plants and in some animal secretions. It is the important constituent of vinegar; but the strongest sold in commerce does not contain more than 5 per cent. of real acetic acid. What should alone be called vinegar is derived from the oxidation of cider and wines, and is a dilute aqueous solution of acetic acid, in which the coloring matter, salts, and other constituents of the cider and wine, are also present. Pure acetic acid is obtained from the distillation of wood, by a process which need not be here described; and much of the vinegar of commerce is such acetic acid diluted with water.

Lactic acid ($HC_3H_5O_3$) exists in muscles, is a possible constituent of gastric juice, is contained in sour but not in sweet milk, and in the preparation of white cabbage known as sauerkraut. In the last two situations it is the result of a fermentation of sugar. It is also one of the acids of sour bread, where, along with butyric and acetic acids, it is the result of permitting fermentation to go too far. The lactic-acid fermentation of sugar takes place in the presence of decomposing nitrogenous

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[1] Letheby: Op. cit., p. 80.

substances, especially casein. Wheat-flour, made into a paste with water, and left to stand for a few days in a warm place, becomes a true lactic-acid ferment, the gluten of the flour being the special ferment.

Citric acid ($H_3C_6H_5O_7$), *tartaric acid* ($H_2C_4H_4O_6$), and *malic acid* ($H_2C_4H_4O_5$) are found in numerous acid fruits, as lemons, grapes, apples, oranges, etc.

3. *Accessory Foods.*

A third group of articles, which belong properly to *indirect* food, though less essential than the inorganic indirect, is that to which the name *accessory diet* has been applied. In this are included alcohol, tea, coffee, chiccory, chocolate, coca, tobacco, opium, spices, etc.—articles which, though evidently not indispensable to nutrition or to life, have yet been so generally used by men throughout all historic time, and are so rapidly extending their use, that they have become an acknowledged part of our food. As such, they have attracted the earnest attention of physiologists and physiological chemists who have laboriously sought to determine their influence.

The late Dr. Anstie, in the Introduction to his "Stimulants and Narcotics," quoting Von Bibra,[1] says that—

"Coffee-leaves are taken, in the form of infusion, by two millions of the world's inhabitants.

"Paraguay tea is taken by ten millions.

"Coca by as many.

"Chiccory, either pure or mixed with coffee, by forty millions.

"Cacao, either as chocolate or in some other form, by fifty millions.

"Haschisch is eaten and smoked by three hundred millions.

"Opium by four hundred millions.

"Chinese tea is drunk by five hundred millions.

"Finally, all the known nations of the world are addicted to the use of tobacco, chiefly in the form of smoke, others by snuffing and chewing."

Prof. Johnston[2] has further illustrated the universal use of these substances in three maps, from which it appears that no extensive portion of the earth's surface exists without some special indigenous narcotic plant, of which the natives freely avail themselves, not only for medicinal purposes, but also for every-day use. And Dr. Anstie further adds: "Nor is the use in every-day life of these substances an outgrowth of modern corruption; on the contrary, it is consecrated by whatever sanction immemorial custom can confer. There is absolutely no period in history, as there is absolutely no nation upon earth, in which we do not find evidence of this custom."

It must be admitted that there is still considerable uncertainty as to the precise mode of action of these substances. It seems, however, highly probable that, so far as their *distinctive*, active principles are con-

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[1] Von Bibra: Die narkotischen Genussmittel und der Mensch, 1855, Preface

[2] Johnston's Chemistry of Common Life, Vol. I., London, 1859.

cerned, they are not converted into tissue. And it is to these principles, in which the peculiar property of the substance resides, that we now devote our consideration, and not to other alimentary matters, in which some abound.

Alcohol.

The ordinary alcohol, to which reference is here made, whether in its purest form of so-called absolute alcohol, or variously diluted in the shape of common alcohol, brandy, whiskey, rums, wine, ales, beers, etc., is *ethylic* alcohol. It is composed of carbon, hydrogen, and oxygen, and is represented by the formula C_2H_6O. In consequence of its strong affinity for water, alcohol cannot remain pure when in the least degree exposed to the atmosphere, and even the so-called absolute alcohol in the purest state attainable after repeated distillations, probably contains from 2 to 5 per cent. of water, and, immediately on exposure to air, increases this percentage, and becomes 90 per cent. alcohol.

Wherever present, and however obtained, alcohol is always a product of fermentation of substances containing sugar, which is mainly converted by this process into carbonic acid and alcohol. The alcohol thus formed exists in combination with water and such other bodies as may have been present, together with small amounts of substances allied to alcohol, also formed in fermentation, and called "ethers." From any of its solutions it is obtained in a purer state by distillation. Other matters with which it is combined in the different fluids and beverages will be named when these are separately considered.

With regard to the physiological action of alcohol, it was held by Liebig,[1] Bouchardat, Sandras, and Duchek,[2] that it undergoes conversion into hydrocarbons (fat), which, in their oxidation, develop heat, thus performing the special office of this class of food.

More recent observations, by Dr. E. Smith,[3] in England, and MM. Lallemand, Duroy, and Perrin,[4] in France, failed to confirm this view, but went to show, on the other hand, that alcohol is partly eliminated by the lungs, skin, bowels, and kidneys, while a considerable quantity is found in the tissue of the brain many hours after the dose has been taken, as was shown some years earlier by Dr. Percy.[5] According to these experimenters, very little alcohol is destroyed in the body. Still more recently, M.

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[1] Liebig: Animal Chemistry in its Relation to Physiology and Pathology, translated by Dr. Gregory, London, 1846.

[2] Duchek: Ueber das Verhalten des Alcohols im thierischen Organismus, Prag. Vierteljahrschrift, X., 3, 1853.

[3] Edw. Smith, M.D.: Cyclical Changes, London, about 1861; also, by the same author: Foods, New York, 1873, p. 420.

[4] Lallemand, Perrin et Duroy: Du rôle de l'alcool et des anesthétiques dans l'organisme, 1860.

[5] Percy: Prize Thesis; An Experimental Inquiry concerning the Presence of Alcohol in the Ventricles of the Brain, London, 1839.

Baudot[1] in France, Schulinus in Germany,[2] and Drs. Anstie,[3] Dupré,[4] and Thudichum in England,[5] have shown that the quantity eliminated by these channels is so small, that it is insufficient to account for the entire bulk which disappears, and which, they contend, is consumed in some way in the economy, though precisely how they do not pretend to show. Dr. Anstie[6] suggests that more careful and extended research may some day show that alcohol is transformed into aldehyde and thence into acetic acid, as Bouchardat, Sandras and Duchek first attempted to prove;[7] or into acetic acid, of which there is trifling evidence in the increased acidity of the urine during the use of alcohol. But, with regard to these results, Subbotin[8] says, even supposing it true that so small a quantity of alcohol is eliminated by the channels referred to, it does not follow from this that the remaining alcohol is transformed in the body and acts as food in the sense claimed for it by Liebig.

Subbotin experimented upon rabbits enclosed in apparatus in which the exhalations of the lungs and skin could be collected and examined for alcohol. The urine was also examined for the same substance. The experiments showed that in the first five hours after the introduction of 3.45 grammes of alcohol into the stomach of a rabbit, about 2 per cent. was eliminated by the kidneys, 5 per cent. by the lungs and skin; and experiments, extending over a greater length of time, led to the conclusion that usually, during twenty-four hours, at least 16 per cent. of the ingested alcohol leaves the body in an unchanged condition (or perhaps as aldehyde), and that besides this elimination by the lungs, skin, and kidney, a portion of the alcohol is oxidized in the organism. Although, by this oxidation, force must be set free in the organism, Dr. Subbotin does not consider that alcohol is on that account to be regarded as nutriment, for the functions of the animal body depend, according to him, upon the transformation of living material, *i. e.*, of the constituent parts of the body, and not upon the oxidation and decomposition of matter foreign to the body.

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[1] Baudot: Union médicale, Septembre et Novembre, 1863.

[2] Schulinus: Archiv der Heilk., 1866.

[3] Anstie, Francis E., M.D.: Stimulants and Narcotics; their Mutual Relations, London, 1864, p. 419 et seq.

[4] Dupré, A.: On the Elimination of Alcohol; a paper to the Royal Society, abstracted in the Medical Times and Gaz., Vol. I., 1872, p. 196.

[5] Thudichum: In Letheby on Food, New York, 1872, p. 92.

[6] Anstie: Op. cit., pp. 431 and 417.

[7] In the paper referred to, Dr. Dupré not only states that "the amount of alcohol eliminated in both breath and urine is a minute fraction of the amount of alcohol taken," but also confirms certain observations of M. Lieben, who has shown that a substance exists in the urine of man and animals which is not alcohol, though it yields iodoform, and *gives the green reaction with potassic bichromate and sulphuric acid.* But the recent experiments of Subbotin, related in the text, reaffirm the original position, that at least some alcohol is eliminated.

[8] Subbotin: On the Physiological Importance of Alcohol for the Animal Organism, Zeitschrift für Biologie, VII., 361. See, also, a paper read by Prof. H. P. Bowditch, M.D., before the Boston Society of Medical Sciences in the early part of 1873.

But whatever the difficulties in the way of admitting alcohol among tissue-producing food, there is no doubt that it comes within the limits of our definition, which, it will be recollected, includes *all substances which directly or indirectly contribute to the processes of nutrition, whether they be directly converted into tissue, produce force by oxidation, or prevent the destruction of necessary elements.*[1] For although the testimony as to the effect of the ingestion of alcohol upon the amount of carbonic acid exhaled from the lungs is somewhat conflicting, yet the most constant result would seem to be to decidedly diminish such exhalation, as well as the discharge of urea and excrementitious substances generally, thus diminishing the waste of the tissues. Among the earliest observations in this direction were those of Dr. William A. Hammond, of New York, who proved in experiments upon himself, made in 1856, 1st, that if the system be so nourished that its weight is stationary, the ingestion of twelve drachms of alcohol for five days resulted in an increase of weight corresponding with the decrease in the quantity of excretion, though this was attended by some disturbance of the general health and mental faculties; 2d, that the loss of weight consequent upon insufficiency of food may be temporarily arrested, and even more than compensated by the use of the above quantity, twelve drachms for the same period, while the unpleasant symptoms present, when an undiminished food was taken, did not appear; 3d, that the increase in weight, due to the use of more than sufficient food, is further augmented by the use of the same amount for the same period, while the unpleasant symptoms are also increased.[2] Further experiments by E. Smith[3] and others are not uniform in their results, but all show that there is at least no increase in the carbonic acid eliminated, while many prove a diminution in tissue metamorphosis. It is true the late Dr. Parkes says: "This is usually stated to be lessened, and it has been said that there is a diminution in the elimination of nitrogen (as urea) and of carbon (as carbonic acid). But the experiments already referred to by Count Wollowicz and myself prove that the metamorphosis of nitrogenous tissues is in no way interfered with by dietetic

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[1] This is practically also the definition of Prof. Voit, given in a note appended to Dr. Subbotin's essay, and is that now generally received. That of the last-named writer is much more limited, and would exclude alcohol even from indirect food, in which we place it. Prof. Voit, on the other hand, would regard alcohol as nutriment, "since under its influence fewer substances are decomposed in the body." But he says further that, "since alcohol, when taken in considerable amount, causes disturbance in the processes of the animal economy, we cannot introduce it in quantities sufficient for nourishment as we do other nutriments, and in the amount which we can take without injury its importance as a nutriment is too small to be considered." On this point he says he agrees entirely with Dr. Subbotin—"we use alcohol, not on account of its importance as a nutriment, but on account of its effects as a stimulant or relish."

[2] Hammond, W. A., M.D.: The Physiological Effects of Alcohol and Tobacco upon the Human System, in Physiological Memoirs, Phila., 1863, p. 48.

Also American Journal of the Medical Sciences, New Series, Vol. XXXII., Oct., 1856, p. 306.

[3] Binz: Journal of Anatomy and Physiology, 1874.

doses. Whether the carbonic acid excretion is really lessened may also be questioned."[1]

But most of the evidence favors the conclusion that alcohol diminishes the waste of the tissues and renders a less amount of food necessary. Of this there is now ample confirmation in clinical and every-day experience. That alcohol, in the treatment of fever and wasting diseases, in some way supplies the place of deficient aliment, is now an admitted fact, while the experience of those who are compelled, in civil or military life, to temporarily undergo privations in which insufficient food is an element, attests the conservative power of alcohol. This is, however, not to be interpreted as implying any efficiency in alcohol to protect against the effects of extreme cold.

As to the mode in which this effect of alcohol is accomplished, although not fully established, it has perhaps been placed outside the limits of pure speculation. It would seem that Prof. Lionel Beale, Dr. James Ross, and Prof. Binz arrived, independently of each other, at practically the same conclusion, that *alcohol restrains the rapid growth of young cells*,[2] standing in the same rank with quinine, which has been shown by Binz[3] and others to possess the remarkable property of checking the multiplication of the white corpuscles of the blood and the low organisms developed in putrefactive processes.

Caution should, however, be exercised to restrict alcohol to its legitimate position, and there is no doubt that it has acquired a reputation in certain directions which is fictitious. One of these is that of enabling the consumer to endure extreme cold for a considerable length of time, an office which an increased quantity of direct aliment can alone fulfil. To this end we have the testimony of numerous arctic explorers, among whom Dr. Hayes is very explicit. He says: "While fresh animal food, and especially fat, is absolutely essential to the travellers and inhabitants in arctic countries, alcohol is, in almost any shape, not only completely useless, but positively injurious." He admits that it may be of temporary advantage in cases of great exhaustion from cold and exposure, but only if more substantial succor be near at hand; while he has known the most unpleasant consequences result from the injudicious use of whiskey for the purpose of temporary stimulation, and has known strong, able-bodied men to become utterly incapable of resisting cold in consequence of the long-continued use of alcoholic drinks.[4]

To a similar end is the experience of the leaders of the great Napo-

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[1] Parkes: Practical Hygiene, 5th Ed., 1878, p. 296.

[2] Anstie: Remarks on certain recent Papers on the Action of Alcohol, Practitioner, No. LXV., Nov., 1873.

[3] Binz: Experimentelle Untersuchungen über das Wesen der Chininwirkung, Berlin, 1868.

Baxter, E. Buchanan: The Action of the Cinchona Alkaloids and some of their Congeners on Bacteria and Colorless Blood-Corpuscles, The Practitioner, No. LXV., Nov., 1873.

[4] Hayes: Observations upon the Relations Existing between Food and the Capabilities of Men to Resist Low Temperatures, Amer. Jour. Med. Sci., July, 1859, p. 117.

leonic campaign in Russia, and the monks of St. Bernard,[1] all of whom assert that death from cold is accelerated by alcohol, which reduces, in truth, the animal temperature; a fact which has been amply confirmed, first, by the clinical experience of the late Dr. Todd, of London, as well as by recent observations on the effect of alcohol upon the high temperature of fever.[2]

Add to this the well-known baneful effects of an excessive indulgence in alcohol—and it seems to us quite impossible to separate entirely the consideration of the abuse from the use of so important a substance—and there can be little doubt of the propriety of restricting its use, except at least in a very dilute form, to those occasions where wasting disease or temporary causes of fatigue and prostration demand its conservative and stimulating properties. These remarks apply to pure alcohol, and such alcoholic liquors as contain it in large amounts, as whiskey, brandy, gin, rum, and other liquors containing a large proportion of alcohol, which receive different names according to their source or the language of the country in which they happen to be especially produced or consumed.

In addition to the ethylic alcohol, which is the chief alcohol of these liquors, other alcohols, differing in composition, but similar in properties, are also formed in some fermentations. Among these are methylic and amylic alcohol. The latter is the well-known *fusel-oil*, which is present in larger proportion in the more common forms of whiskey, especially that obtained from potatoes, whence the name. It is, however, an impurity which is to be watched for in all whiskeys, as it greatly increases their intoxicating and other pernicious effects.

Wines.

Wines which, when pure, are derived from the fermented juice of the grape, contain from 8 to 25 per cent. of alcohol, together with other sub-

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[1] Richardson, B. W.: Popular Science Rev., April, 1872.

[2] Bouvier, Cuny: Effect of Alcohol on Reducing the Temperature of the Body, Phila. Medical Times, Vol. II., 1872, p. 198, from Centralblatt, No. 51. Also, by the same author: Studien über Alcohol, Bonn, 1872.

Binz: Ueber die antipyretische Wirkung von Chinin und Alcohol, Virchow's Archiv, B. 51, 1870. Effects of Alcohol in Reducing the Temperature of the Body. Oct. 4, 1873.

For Results of the Researches of Ringer and Rickards, see London Lancet, Vol. II., 1866.

Godfrin: De l'Alcohol, Paris, 1869.

Socin: Kriegschirurgische Erfahrungen, gesammelt in Carlsruhe, 1870 und 1871.

And for a very complete history of the entire subject from the first observations of Lichtenfelt and Fröhlich in 1852, to the present time, see Anstie, in the Practitioner, Nos. LXV. and LXVI., November and December, 1873. The opposite results of Dr. Parkes, published in Transactions of the Royal Society, 1871, which, from the high position of their author, must not be overlooked, are here also discussed by Dr. Anstie, who says that these matters are not to be decided in healthy individuals or in ephemeral pyrexias. In recent editions of his work on Hygiene, Dr. Parkes admits a slight reduction of temperature in some cases.

stances which materially modify or add to the effect of pure alcohol, making them tonics, and to a certain extent direct nutrients. Among these principles are sugar, gum, extractives, gluten, or, in its absence, tannin, acetic acid, salts of potash and alumina, sodic and potassic chlorides, and carbonic acid. In addition, wines also contain bodies allied to alcohol and formed during fermentation or in subsequent chemical changes, called "ethers." These are very numerous—according to Dr. Dupré, there are twenty-five or more—although some are in very small quantity. Some of them are œnanthic, citric, malic, tartaric, acetic, etc. It is to these, and especially to œnanthic ether, that the "bouquet" of wines is due.

When the quantity of sugar which is present in the juice of the grape is not large, all of it is converted into alcohol, producing a *dry* wine; but if the amount is large, about 20 per cent. of alcohol is produced, which is sufficient to prevent the further conversion of sugar, and the product is, therefore, a *sweet* wine.[1]

Malt Liquors.

The various malt liquors, beer, ale, porter, brown stout, etc., are prepared from malted or germinated barley and flavored with hops. They contain a very large proportion of nutrient matter and a very small proportion of alcohol. Of the latter they contain 1 to 8 per cent., but may reach 10 per cent. in the strong East India pale ale, or even 15 per cent. in certain English home-brewed ales, stored for private use.[2] The ordinary German *lager bier*, now so largely consumed in this country, contains about 2 per cent. of alcohol, and is the weakest and most harmless of the alcoholic drinks. The nutrient matters, which are abundant, include a large proportion of saccharine and nitrogenous substances—sugar, starch, gum, gluten, lupulin, vegetable fibre, coagulated albumen—together with phosphate of lime, water, and a peculiar volatile oil produced on distillation, which gives the aroma to beer. These constituents give a tonic and nutrient property to the malt liquors, which make them most valu-

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[1] The following table, containing the approximate amount of alcohol in various liquors, is introduced from the useful little work on Alcohol: its Use and Abuse, by Dr. W. S. Greenfield, 1879:

Whiskey	50 to 60	Claret, mean	15
Brandy	50 to 60	Claret, vin ordinaire	8 or 9
Rum	60 to 77	Champagne	5 to 13
Gin	49 to 60	Hock	9 to 12
Port-wine, strongest	25	Sauterne	14
Port-wine, ordinary	23	Cider	5 to 10
Port-wine, weakest	16.5	Ale, Burton	9
Madeira	16 to 22	Ale, ordinary	3 to 5
Sherry, strongest	25	Perry	7
Sherry, weakest	16	Brown stout	6 to 7
Burgundy	10 to 14	London porter	4.2
Claret, strongest Bordeaux	17	London small beer	1.28

[2] Smith, Edw., M.D.: Foods, New York, 1873, p. 412.

able adjuvants in the treatment of enfeebled states of the system from whatever cause induced, as well as comparatively harmless beverages.

Cider and *Perry* are derived, the first from the fermented juice of the apple, and the second from that of the pear. Containing at first but a small quantity of alcohol, this may become increased to from 5 to 10 per cent. In addition to alcohol, they contain carbonic acid, saccharine matter, and the various organic acids and salts of the fruit whence derived and by which they are flavored. When properly prepared and bottled, ciders are not unlike champagne in flavor and effect.

The further fermentation of cider results in vinegar or acetic acid.

Tea and Coffee.

Tea is the dried leaves of a number of tea-plants grown in China, Japan, and lately also with some success in Ceylon, Australia, in California and other Western States of this country, as well as in North and South Carolina. The *green* and *black* teas are varieties due to different methods of preparation, the color of the former being retained by the rapidity of the drying process ; while the tea, to become black, is exposed to atmospheric changes for a longer time until the process of fermentation is set up.

Coffee is the bean of the coffee-plant (Coffea Arabica), originally a native of Arabia and Abyssinia, but now naturalized in many tropical countries. The beans are in pairs, placed face to face, and enclosed in a hard coreacious membrane, further surrounded by a pulpy pericarp.

Both tea and coffee are used in the shape of infusions ; but the latter is almost universally first roasted, in the process of which it develops desirable aromatic qualities, becomes more friable, and loses about 20 per cent. in weight when it reaches the proper stage, indicated by a chestnut-brown color.

Although they contain other substances, as casein or legumin, gum, sugar, tannin, starch, aromatic oil, fat, vegetable fibre, mineral matters and water, the peculiar essential properties of both tea and coffee are due to an active principle, identical in composition, though in the former it is called *theine*, and in the latter *caffeine*. Its chemical formula is put down as $C_{16}H_{50}O_4N_4+H_2O$.

As to the physiological effect of tea and coffee, it is apparent, from their composition, that their direct nutritive value cannot be very great. It is, however, larger in coffee, of which an infusion of 1,500 grains (97.19 grammes) in a quart of water contains about 300 grains (19.438 grammes) of soluble principles. Of these, about 140 grains (9.007 grammes) are nitrogenous matter, and 153 grains (9.978 grammes) fatty, saccharine, and saline substances.[1] Yet that they supply some hidden want of our nature

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[1] Payen: Précis Théorique et Pratique des Substances Alimentaires, Paris, 1865, p. 414.

might be inferred from their widespread use. Experience and experiment have confirmed such inference. First, as to those effects upon the mind and body, which have come under the observation of every one. The chief of these are a feeling of refreshment, especially after fatigue, and a capacity for further mental and physical effort. Few individuals who are called upon for considerable mental or physical exertion have failed to confirm this effect; while the experience of armies, and of communities like the Belgian miners of Charleroi, whose condition was investigated by De Gasparin,[1] has led to similar conclusions. The testimony of Dr. Hayes as to these effects of tea and coffee, and their superiority over alcohol in enabling men to endure cold and hardship in arctic regions, points in the same direction. "They both operated upon fatigued and overtaxed men like a charm;" but coffee was preferred in the morning and tea in the evening. "The coffee seemed to last throughout the day, and the men seemed to grow hungry less rapidly than after drinking tea, while the tea soothed them after a day's hard labor and enabled them better to sleep."[2]

This reinvigorating and stimulating influence upon the mind, if unduly increased, leads to wakefulness, an effect so well known that both tea and coffee are commonly resorted to when it is desired to avert the disposition to sleep. Carried still farther, the effect is to produce nervousness and tremor, and, if sleep be obtained, it is often disturbed. These effects are much more promptly induced in some persons than in others, some being unable to take a single cup of either beverage without experiencing them to an inconvenient degree. A friend of the writer, an accomplished surgeon, cannot take a cup of coffee at breakfast preceding an operation.

These effects are common to both tea and coffee, but are thought to be possessed in a higher degree by the latter; but here, too, much depends upon idiosyncrasy, certain individuals being more refreshed by one than by the other, and a cup of strong coffee will keep one person awake for many hours, while it will have no effect whatever upon another, whom tea may affect strongly.

With regard to special experiments made with a view to determining the effects of these substances, those of Böcker,[3] in 1853, and of Lehmann,[4] in 1854, were the first whose results were generally acknowledged, and they are still accepted by many.

These experiments, made with infusion of roasted coffee and caffeine, went to show that their chief influence was to retard the waste of the tissues; the amount of urea and phosphoric acid excreted by the kidneys being less than one-third what was excreted when the same food was taken without the coffee. The empyreumatic oil was found to have a stimulat-

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[1] De Gasparin: Note sur le Régime des Mineurs Belges, Comptes rendus, Paris, 1850, Tome XXX., p. 450. This writer found that often insufficiency of food was associated with the laborious occupations of these people.

[2] Hayes: Loc cit., p. 118.

[3] Böcker: Archiv d. Vereins f. gemeinsch. Arbeit, 1853.

[4] Lehmann: Liebig's Annalen, Bd. LXXXVII., p. 205.

ing effect upon the nervous system, promoted perspiration, dispelled hunger, and moved the bowels; and, in excess, caused excitement and wakefulness. In retarding the waste of the tissues it had an effect quite equal to the caffeine itself.[1] Lehmann concluded from these experiments that both tea and coffee exhilarate the nervous system, and, by diminishing the waste, render a less amount of food necessary, while with a given amount of food more work could be done under the use of tea and coffee than without them.

The experiments of Hammond[2] confirm these conclusions; but the more recent experiments of Dr. Edw. Smith lead to opposite results, so far as the effect of both tea and coffee upon the tissues is concerned. According to his observations, both are respiratory excitants, causing a largely increased evolution of carbonic acid, promoting the transformation of food without supplying nutriment, and *therefore increasing the waste.*[3] He denies that a diminished elimination of urea implies diminished waste of the tissues, since not urea, but carbonic acid, is the measure of tissue change.[4]

He points out also certain differences in the action of tea and coffee, some of which coincide, and others disagree, with the results of Lehmann. While both are powerful respiratory excitants, increasing the elimination of carbonic acid, coffee causes an increase in the rate of respiration, so that the depth of the respiration is but slightly increased, and there was an increase in the rate of the pulsation. Again, tea promotes very largely the action of the skin, inducing perspiration; while coffee decreases it, and therefore dries that organ, while it promotes the action of the bowels. By increasing the action of the skin, tea lessens the force of the circulation, cools the body, and does not cause congestion of the mucous membranes; while coffee, by diminishing the action of the skin, diminishes the loss of heat, but "increases the *vis-a-tergo*, and therefore the heart's action and the fulness of the pulse, and excites the mucous membranes."[5] With this difference in the action of tea and coffee upon the skin most are familiar, and therapeutical advantage of it is often taken when diaphoresis is desired. Few agents in common use are so efficient in this direction as tea.

Dr. Smith reaches further conclusions in his observations, which are interesting and important, if correct. He says: "The conditions, therefore, under which coffee may be taken are very different from those suited to tea. It is more fitted than tea for the poor and feeble. It is also more fitted for breakfast, inasmuch as the skin is then active, and the heart's action feeble; whilst in good health, and with sufficient food, it is

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[1] Johnston: Chemistry of Common Life, edited by Lewes, London, 1859, Vol. I., p. 204.

[2] Hammond: Urological Contributions, American Journal of the Medical Sciences, April, 1856, p. 335.

[3] Smith, Edw. M.D.: Foods, New York, 1873, p. 349 et seq., and p. 365.

[4] Idem: Op. cit., p. 367.

[5] Idem: Op. cit., p. 366.

not needful after dinner, but, if thus drank, should be taken soon after the meal. Hence, in certain respects, tea and coffee are antidotes of each other, and we know that they are not taken indiscriminately, although in a chief action they are interchangable."[1]

Voit,[2] from observations on a dog, and Squarey,[3] from experiments on men, conclude that coffee possesses little or no influence on the general nutrition of the body.

Whatever the effect of tea and coffee upon the tissues, the similarity of their exhilarating effect to that of alcohol leads naturally to their being placed in the same group, while their harmlessness and more permanent effects render them much more suitable beverages than alcohol. It need scarcely be mentioned that the direct nutrient properties of tea and coffee are greatly increased by the milk and sugar with which they are so largely used.

Chiccory, with which coffee is often mixed, is the root of the *cichorium intibus*, a plant growing in all European countries, and now much cultivated. It has been considered nearly inert, and as giving only color and a certain body to the infusion of coffee; but the experiments of Dr. Edw. Smith have shown it to possess similar properties with coffee, though in a very much less degree. In preparation, it is cut into pieces and roasted with fat, as coffee is roasted. It is sometimes adulterated with roasted rye, with which coffee also is known to be adulterated in this country, forming, with molasses, a large proportion of the so-called "extracts" of coffee, at one time much sold in America.

Maté, or Paraguay tea, is the prepared leaves of the Brazilian holly, or *Ilea Paraguayensis.* It is similar to China tea in its effects, which are due to the same active principle. It is, however, less delicate in flavor, more bitter and astringent, and is said to be more narcotic than China tea.

Rapidly dried *coffee-leaves* are also used infused, in Java, Sumatra, and other countries. They contain a small proportion of caffeine; but the results of some experiments by Dr. Edw. Smith[4] were opposed to those of the same observer on tea and coffee, showing that coffee-leaves are not respiratory excitants.

Chocolate.

Chocolate is prepared by admixture with sugar of the powdered seeds of the *Cacao theobroma*, or cocoa-palm, and the pods of the *Arachis hypogæa*, the cacao shrub of Zanzibar.

Chocolate contains, besides the peculiar principle *theobromine* ($C_7H_8N_4O_2$), which seems identical in its properties with theine and caffeine, large amounts of fat and sugar, which give it the properties of direct aliment. These are further contributed to by the large quantities of milk

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[1] Smith: Op. cit., p. 367.

[2] Henle and Meissner's Bericht, 1860, p. 402.

[3] Parkes: Practical Hygiene, p. 238.

[4] Smith, Edw.: Op. cit., p. 358.

always taken with it. It is less stimulating to the nervous system than tea and coffee, but is, of course, more nutritious.

Guarana and Coca.

Guaranine and cocaine are nearly, if not quite, identical in their action with theine, caffeine, and theobromine.[1] The former is the fixed principle of *guarana*, which is derived from the seeds of *Paullinia sorbilis, P. cupana*, and several other climbing plants of the order *Octandra trigynia* of the Linnæan system. Cocaine is the active principle of *Erythroxylon coca*. The formula for guaranine is the same as for theine and caffeine, and that of cocaine is $C_{16}H_{19}NO_4$. The latter was discovered by Gaedeke in 1855, and further examined by Neiman in 1859.

Guarana is prepared and used in Brazil in the same manner as coffee. It has recently acquired considerable reputation as a cerebral stimulant in headache.

Coca-leaves are likewise used in infusion, but are also largely chewed as tobacco. It forms always an important element in the food of the native South American, and some of the published accounts of the endurance they are enabled to sustain by its use alone, though almost incredible, are well authenticated. For example, the Indian mail-carriers and messengers are said often to travel three or four days without any food except coca, carried in a little bag at the side. Von Tschudi relates that an Indian, sixty-two years old, worked for him at excavation for five days and nights consecutively without any ordinary food, and with a very short allowance of sleep, and yet, at the end of that time, was fresh enough to undergo a long journey, being sustained only by the coca which he chewed from time to time.[2]

The results of experimental inquiry into the effects of coca are not uniform, but the very carefully conducted experiments of Dr. Isaac Ott[3]

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[1] See a paper by Alexander Bennett, M.D.: An Experimental Inquiry into the Physiological Actions of Theine, Caffeine, Guaranine, Cocaine, and Theobromine, Edinburgh Med. Jour., Oct., 1873, p. 323.

[2] Anstie: Stimulants and Narcotics, London, 1864, p. 143.

The writer is informed by one of his former pupils, Dr. Hermann N. Loeb, long resident in South America, that the coca is always chewed with a small fragment of a substance called *yechta*, which is composed of ashes, a "particular kind of mud," and common salt. These three, when thoroughly mixed and sun-dried, form a hard substance, which is used in quantity the size of a pea. It has a smarting taste, and is always chewed together with a mouthful of coca.

For other interesting matter on this subject, see also the following:

Von Tschudi: Travels in Peru.

Markham: Travels in Peru and India.

Poppig: Reise in Peru, Bd. II.

Montegazza: Prize Treatise on, Milan, 1859: Abstract in the British Pharmaceutical Journal for 1860.

Reis: In Bouchardat's Annuaire Thérapeutiques for 1864.

Weddell: Voyage dans le Nord de Bolivie.

[3] Ott: Cocain, Veratria and Gelsemium, Toxocological Studies, Philadelphia, 1874.

revealed that, during the use of coca for five days, the solid elements of the urine diminished, while the weight of the body slightly increased. The urine also contained oxalate of lime crystals during its use. Christison found that it increased the saliva and probably also lessened the elimination of the urinary solids. Gazrau, on the other hand, found that coca augmented the urea and lessened the body weight. From a personal knowledge of Dr. Ott's careful and accurate method of investigation, the writer is inclined to accept his conclusions, which are confirmed by Christison so far as he goes.

Tobacco.

Similar properties are claimed for tobacco, which is also said to have the power of replacing ordinary food for a limited period. Tobacco was made the subject of experimental observation by Dr. Hammond,[1] who, quite unaccustomed to its use, smoked 150 grs. (9.7 grammes) of tobacco thrice daily for a series of days. He found that while the food consumed was sufficient to preserve the weight of the body, the tobacco increased that weight, and, when the food was not sufficient, and the body lost weight in consequence, the tobacco restrained that loss. He found, moreover—

1st. That tobacco did not materially affect the excretion of carbonic acid by the lungs.

2d. That it lessened the amount of aqueous vapor given off in respiration.

3d. That it diminished the amount of fæces.

4th. That it lessened the quantity of urine and the amount of its urea and chlorine.

5th. That it increased the amount of free acid, uric acid, phosphoric and sulphuric acid eliminated through the kidneys.

In comparison with Hammond's observations on the use of alcohol, we have a difference in the 1st result, carbonic acid having been diminished. There is a coincidence in the 2d, 3d, and 4th; but in the experiments with alcohol, the free acid, uric, sulphuric, and phosphoric acids of the urine were also diminished. Dr. Hammond can only account for the increase in the phosphoric and sulphuric acids by the increased consumption of nervous matter.

Notwithstanding the effect of tobacco in diminishing the total amount of fæces, it is a matter of every-day experience that the smoking of a cigar will often induce a stool, and is frequently resorted to for that purpose. This effect may be directly due to an increased secretion of gastro-intestinal mucus;[2] and to it may be ascribed the beneficial results which have been observed in its moderate use in dyspepsia, of which also, in excessive amounts, it is a prolific cause.

The tranquillizing effect of the moderate consumption of tobacco, es-

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[1] Hammond: American Journ. of Med. Sci., N. S., Vol. XXXII., Oct., 1856, p. 315.

[2] Morris, J. C.: On Tobacco., Phila. Med. Times, Vol. I., 1870–71, p. 211.

pecially by smoking, and the phenomena of nervousness shown in trembling and wakefulness, etc., from excessive use, are as well known as the similar effects of tea and coffee. They were also experienced by Dr. Hammond.

Opium.

However much it be conceded that the use of opium were better confined to medicinal purposes, the fact still remains that it is practically used as food by a large number of the Caucasian race, as well as the Orientals; and it becomes us to consider what are its effects. These, from clinical and general observation, are also determined to be conservative, so far as tissue consumption is concerned. Few hospital or practising physicians have failed to see life prolonged in exhausting disease, and during inability to take sufficient food, by the use of moderate quantities of opium; while the long lives of opium-eating crones have not failed to impress the writer. The most striking instance of this food-action of opium is quoted by Dr. Anstie from Dr. Barnes,[1] who says: "On one occasion I made a very fatiguing night-march with a Cutchie horseman. In the morning, after having travelled thirty miles, I was obliged to assent to his proposal of halting for a few minutes, which he employed in sharing a quantity of about two drachms of opium between himself and his jaded horse. The effect of the dose was soon evident in both, for the horse finished a journey of forty miles with great apparent facility, and the rider became absolutely more active and intelligent." It must be conceded that it is not easy here to separate the simple stimulant action from the food action. The latter is, however, shown in the length of time in which the exertion was subsequently maintained without the use of other food.

Of opium, however, it must be said, as of alcohol, that, at least with the Caucasian race, the use is so liable to lead to a most pernicious abuse, that it is better restricted to the category of remedies than to that of food.

Condiments.

These substances, including pepper, mustard, spices, etc., although used throughout the world, seem to possess only the property of stimulating the secretion of the digestive fluids, and, by imparting a flavor to food otherwise insipid, to render it palatable.

A Mixed Diet necesssary.

With regard to organic food, there is abundant evidence to prove that none of the four kinds enumerated is alone sufficient to sustain life for any length of time, but that a mixed diet is necessary. Such evidence is derived from four sources: 1st, instinctive proclivities; 2d, the compara-

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[1] Anstie, Op. cit., p. 148: from Barnes's "A Visit to Scinde," p. 230.

tive anatomy of the organs of digestion; 3d, experiment and experience; 4th, a comparison of the amount of carbon and nitrogen daily excreted, with the composition of bread and meat. First, with regard to instinctive proclivities, although in antiquity we find whole tribes designated in accordance with the food they ate, as *ichthyophagi*, or fish-eaters, the *hylophagi*, or feeders upon shoots of trees, we have no evidence that these articles were their exclusive food. And we note that where, in consequence of geographical causes, nations or tribes have been more or less limited to a certain kind of food, as their knowledge grows, and the advantages of commerce are opened to them, one of the first results is an increase in the variety of aliment; while in the most enlightened communities it would appear that one of the chief objects of man's efforts is to obtain not only an abundance, but also a maximum variety of food.

Second, the anatomy of the digestive apparatus of man, compared with that of the herbivora and carnivora, indicates also the kind of food he is intended to consume. This apparatus in man is not as simple as in the carnivora, nor as complex as in the herbivora, but intermediate. A reasonable inference from this fact is, that it was designed that man should subsist not upon a purely vegetable aliment nor upon an animal one, but that he should use mixtures of both.

Third, most satisfactory evidence is derived from experiment and experience. In evidence from the former source may be enumerated the following:

1. The early experiments, in 1769, of Dr. Stark,[1] of London, who subsisted for forty-four days upon bread and water, for twenty-nine days on bread, water, and sugar, and for twenty-four days upon bread, water, and olive-oil, until his health became impaired, and he died in consequence.

2. Magendie[2] proved, in 1817, that dogs, which are omnivorous in the domestic state, if fed exclusively upon non-nitrogenous food (oil, gum, sugar), died in from the thirty-second to the thirty-sixth day, with all the symptoms of inanition; and, a little later,[3] that while dogs lived very well on brown military bread, which contains a variety of alimentary principles, the same animals, fed on pure wheaten bread and water, did not live more than fifty days.

3. The experiments of Tiedmann and Gmelin,[4] published in 1827. These experimenters fed geese exclusively upon gum, sugar, starch, and coagulated white of egg respectively. The one fed on gum died on the sixteenth day, that on sugar the twenty-first; the two fed on starch on the twenty-fourth and twenty-seventh days; and the one fed on white of egg on the twenty-sixth day.

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[1] The works of the late Wm. Stark, M.D., by Dr. James Carmichael Smyth, London, 1788.

[2] Magendie: Précis Élémentaire de Physiologie, première éd., Paris, 1817, Tome II., p. 390.

[3] Idem: ibidem, deuxième édit., Paris, 1825, p. 493; trois. éd., Paris, 1833, p. 504.

[4] Tiedmann and Gmelin: Recherches expérimentales, physiologiques et chimiques, sur la digestion, Paris, 1827, sec. partie, p. 266.

4. Burdach's[1] experiments upon rabbits, in which he fed one animal on potato alone, which died on the thirteenth day; another with barley, which died in the fourth week; and a third, on alternate days with potato and barley successively for three weeks, and afterward on potato and barley together. This rabbit increased in size and appeared well nourished.

5. The results of the French[2] and Amsterdam Commissions, already alluded to, in the former of which were included the use of nitrogenized substances and articles containing a variety of alimentary principles. In these experiments it was shown that dogs could not live upon pure musculine, the appetite failing entirely from the forty-third to the forty-fifth day, while they were well nourished by gluten, which contains a variety of alimentary principles.

6. Finally we have the more recent experiments, published in 1857, of Dr. Hammond,[3] of this country, which, like those of Dr. Stark, being upon himself, are more to the point than any of the preceding, excepting those of Stark. Dr. Hammond found it impossible to sustain health, for any length of time, upon albumen, starch, or gum.

Experience abundantly attests the necessity of a mixed diet. We have only to allude to the sufferings, by scurvy, of seamen long confined to a diet of salt pork and bread, and the effect of the addition to their food of fresh meat and vegetables, sufficiently to illustrate the fact.

Observation has also shown that an habitual excess of any one of the great divisions of food, over and above the wants of the economy, sometimes results in the production of a constitutional derangement, exhibiting itself in various ways, and known in technical language as a "diathesis." Thus, an excess of *albuminous* food, derived from a diet too exclusively composed of animal flesh, produces congestions and enlargements of the liver and the so-called *arthritic* or *gouty* diathesis. In this condition the blood contains an undue amount of unoxidized nitrogenous matter—imperfectly assimilated histogenetic and force-producing material, or partially reduced products of retrograde metamorphosis—which, in their more perfectly oxidized state, are easily separated by the kidneys, but which, unoxidized, are removed with difficulty by these organs. Being thus in excess, they seek to deposit themselves in the urinary passages in the shape of *uric acid* gravel, and in the joints as gouty deposits of the *urates*. An excess of *oleaginous* food tends to produce the so-called *bilious* diathesis, characterized by excessive bile-production and congestion of the liver. This occurs when more hydrocarbons are introduced into the blood than can be effectually oxidized. Part of the excess is converted into bile, and such conversion involves not only a hyperæmia of the liver, but also of the in-

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[1] Burdach, C. F.: Traité de physiologie, traduit par Jourdain, Paris, 1841, Tome IX., p. 249.

[2] Loc. cit.; also Flint: Physiology of Man, Vol. I., 1871, p. 130 et seq.

[3] Hammond: Experimental Researches relative to the Nutritive Value and Physiological Effects of Albumen, Starch, and Gum, when singly and exclusively used as Food: Transactions of the American Med. Ass'n, 1857.

testinal tract, the blood from which has to pass through it. To this may be referred some of the diarrhœas and dysenteries, which are more frequent in hot climates and in warm seasons. An excess of both *starches* and *fats* also retards the metamorphosis of nitrogenous matters, and results in excessive obesity. An exclusive diet of *farinaceous* food, on the other hand, more frequently the result of necessity than of choice among the poorer classes, is thought to cause the rheumatic diathesis, consisting, too, in malassimilation and deficient metamorphosis, in which *lactic* acid or other product of the chemolysis of saccharine compounds becomes the offender. On the other hand, it is well known that *scurvy* is the inevitable result of prolonged absence from food of fresh fruits and vegetables; and it is at least observed that in many of those in whom a *scrofulous* tendency exists there is often repugnance to oleaginous food, while those who best digest and consume fatty food most seldom become phthisical.

Fourth. Further evidence of the propriety of a mixed diet is found in a comparison of the amount of carbon and nitrogen daily excreted by the lungs, skin, kidneys, and bowels, with the composition of bread and meat. Various experiments have shown the former to be, in the routine laborer, about 19.891 grammes (307 grains) of nitrogen and 304.141 grammes (4694 grains) of carbon.[1] According to Payen,[2] 64.79 grammes (1000 grains) of bread contain about 19.438 grammes (300 grs.) of carbon and .647 gramme (10 grs.) of nitrogen: hence, to obtain the 19.891 grammes (307 grs.) of nitrogen required by the system, over 1943.7 grammes (30000 grs.), or more than 1.94 kilogrammes (4.189 pounds), of bread must be consumed. But the 304.141 grammes (4694 grs.) of carbon required are contained in 971.9 grammes (15000 grs.) of bread; so that to obtain the proper amount of nitrogen, a quantity of bread must be consumed containing double the amount of carbon actually required. Again, 64.79 grammes (1000 grs.) of meat contain 6.47 grammes (100 grs.) of carbon and 1.943 grammes (30 grs.) of nitrogen: therefore, to obtain 304.141 grammes (4694 grs.) of carbon, no less than 3041.41 grammes of meat, or 3.041 kilogrammes (6.6 pounds) must be consumed, while the required 19.891 grammes (307 grs.) of nitrogen are contained in 663.26 grammes (1.46 pounds) of meat; so that four times more meat must be consumed to supply the carbon than is necessary to furnish the nitrogen. But let us suppose that a mixed diet of bread and meat is used, when 1000.42 grammes (15440 grs.) of bread and 300 grammes (4630 grs.) of meat would supply nearly the proper amount of carbon and nitrogen.

Thus,

	Grms. of carbon.		Grms. of nitrogen.	
1000 grms. or 1 kilog. (15433.6 grs.) of bread contain...	300	(4630 grs.)	10	(154 grs.)
300 grms. (4630 grs.) of meat contain................	30	(463 grs.)	9	(138.9 grs.)
	330	(5093 grs.)	19	(292.9 grs.)

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[1] H. Letheby: On Food, New York, 1872, p. 110. Deduced from the results of experiments by Messrs. Edw. Smith, Parkes, Haughton, Playfair, Fick and Wislicenus, Ranke, Beigel, Maas and Vogel; Payen's results are nearly the same.

[2] Des substances alimentaires, Paris, 1865, p. 482.

That is, about 1 kilogramme or 2.2 pounds of bread and $\frac{1}{3}$ kilogramme or $\frac{2}{3}$ pounds of meat are sufficient to compensate the daily loss of a healthy man.

Sufficient reason having been assigned for the propriety of a mixed diet, so far as the different elementary articles of food are concerned, a second question, which for a time assumed some importance, was as to whether such mixed food is best obtained from both animal and vegetable sources, or whether one of the two kingdoms can sufficiently supply it. We believe it has never been seriously claimed that man should subsist upon animal food alone; but the question of *vegetarianism*, so called, at one time excited considerable interest. The representatives of this school claimed that the destruction of animal life for purposes of food was not justifiable and insisted that man could subsist upon a purely vegetable diet consistently with the highest degree of health. There is no doubt—indeed, we have already shown, that all the proximate alimentary substances are furnished by the vegetable as well as by the animal kingdom; and the experience of many individuals of the vegetarian school attests the possibility of sustaining life and health under such a regimen. But, apart from the fact, as shown from the above comparison, that a mixed diet is *more easily* obtained by combining the two sources, the intermediate position of the anatomy of the digestive organs of man, as compared with those of the carnivora on the one hand, and the herbivora on the other, shows that he is intended to use a mixed diet of animal and vegetable matter, rather than an exclusive one of either. Experiment also shows that the use of an animal diet tends to raise, and that a vegetable diet tends to lower, the proportion of red corpuscles of the blood.[1] Dr. Carpenter says there is some reason to believe that the substitution of a moderate proportion of animal flesh "seems rather to favor the highest *mental* development;"[2] while the converse acknowledgment of the same author, that "a well-selected vegetable diet is capable of producing (in the greater number of individuals) the highest physical development," is not admitted by Dr. Flint, Jr.[3] The examination of this subject by Dr. Parkes also led him to conclude that the animal and vegetable albuminates serve equal purposes in the economy; that "the meat-eater and the man who lives on corn, or peas, or rice are equally well nourished;" and that the well-fed vegetable-eater "will show when in training, no inferiority to the meat-eater."[4] There still remains the important fact, however, that the necessary mixture of the principles of food is more easily obtained by combining the two sources.

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[1] Carpenter: Principles of Human Philosophy, 7th Edition, p. 79, London, 1869.

[2] Ibid., p. 77.

[3] Flint: Physiology of Man, volume on Alimentation, Digestion, and Absorption, p. 127, New York, 1871.

[4] Parkes · Practical Hygiene, 5th Edition, 1878, p. 200.

Modifications in the Proportion of Different Alimentary Principles demanded by Differences in Temperature and Climate.

Although the propriety of a mixed diet would appear conclusively proven by the facts presented, it is nevertheless true that modifications in the strict application of the principle are required by differences of temperature, due to change of season or climate. Thus, it is well known that the inhabitants of frigid zones consume large amounts of carbonaceous food, in the shape of the fat of seals and whales, while those of torrid zones adhere to a diet composed more largely of farinaceous matter. But even here we have further illustration of the correctness of the general principle in the fact that the Hindoo constantly adds to the rice, which constitutes his chief article of diet, a certain proportion of "ghee," or rancid butter, which he greatly enjoys. Moreover, it is well known that in temperate climates the majority of persons have a decidedly increased relish for fatty articles of food in the winter season, while in the hot weather of summer there is often indisposition to touch ordinary butchers' meat, which, when of good quality, has been found to contain as much as one-half to one-third its weight of fat.[1] It is, indeed, the fact, as we should expect, that among the inhabitants of temperate zones the principle of the propriety of a mixed diet is most strictly carried out, and therefore best illustrated. It was facts of the kind which led Liebig to adopt the classification already given under his name, and which, in a general way, is correct.

THE EFFECTS OF COOKING.

Comparatively small quantities of food of any kind are consumed in the raw state, it being usually subjected to the process of cooking, which includes boiling, roasting, frying, broiling, baking, etc. The changes wrought in food by the cooking process are several. Most important, perhaps, is that by which its *digestibility* is improved. This is accomplished in the boiling, etc., of almost all vegetables and almost all the proximate constituents of meat. But in those processes which involve the cooking of meat without the addition of water, as *roasting*, *broiling*, *baking*, and *frying*, this end is not attained if they be too "well done," since in this condition the albuminous matters are too thoroughly coagulated, and even charred, and their nutritive and assimilative properties thus destroyed. The principle of these processes consists in the sudden application of a high heat—212° to 270° Fahr. (100° to 132$\frac{2}{9}$ C.)—to the exterior. By this means, the exterior is hardened, while the meat retains the juices which are freed by the lower temperature—125° to 250° Fahr. (51$\frac{2}{3}$° to 121$\frac{1}{9}$° C.)—to which the interior is subjected. Baking and frying are less favorable processes, in consequence of the higher heat which is involved. This is particularly true of frying or cooking in fat, though the disadvantage is diminished if the substance fried is coated with crumbs or

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[1] Experiments of Lawes and Gilbert: Philosoph. Transac., Pt. II., p. 495.

batter, by which the hot fat is prevented from penetrating the interior. Young meats, as veal or lamb, and the white meat of poultry, and fish, require a higher temperature and more thorough cooking. The intermuscular areolar tissue is also softened or liquefied in all processes of cooking in which moisture is added or retained, by which, too, its digestibility is improved.

Scarcely less important is the *improved flavor* and *savory odor* which are given to almost all articles cooked, and which greatly stimulate the secretion of the digestive fluids by which they are ultimately to be worked up. The direct causes of these odors and flavors are not precisely known. They are believed to be due to the formation of certain undetermined products, one of which, of organic nitrogenous composition, has been called osmazom.

Finally, the *inorganic salts,* among which the potash salts are prominent, are *largely dissolved* in the expressed juices or the water added in cooking.

Soups and Beef Teas.

The chief representative food in which all these effects are combined are the soups or broths, made with the addition of water during the process of cooking, although the flavoring and odoriferous substances are perhaps not so highly developed as in some other processes, especially broiling and roasting. Soups contain chiefly gelatin, extractive matters, the salts, and some floating fat. Albuminous substances are insoluble in hot water, and, coagulating, remain with the meat if it has been immediately placed in hot water. If, however, the water, when first added, be cold, the free albumen is dissolved in it, but coagulates as the water becomes hot, and is removed with the scum. The flesh remaining contains, however, the most nourishing constituents, the myosin and gelatin producing tissues and, in the first instance, also the albumen, but no longer the pleasantly flavored portions or the salts,[1] which have gone over into the water or soup. The solid particles of the meat should therefore be comminuted and retained, not thrown away, as has been the custom in the "beef essence," so called, prepared for the sick. Soups, as ordinarily prepared, contain, after the meat is withdrawn, but from nine to ten parts in the 1,000 of solid matter,[2] and we may well be surprised that so much nutritive power should have been ascribed to them. Doubtless some advantage accrues from the stimulating effect upon the heart, of the alkaline salts, which the concentrated broths contain in considerable quantity. Something similar to this seems indeed to have been Liebig's view with regard to the effects of beef-tea and extract of beef. For, in a recent communication, he says, he "never asserted that beef-tea and extract of meat contained substances necessary for the formation of albumen in the

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[1] Hermann : Grundriss der Physiologie des Menschen, Vierte verbesserte und vermehrte Auflage, Berlin, 1872, p. 191.

[2] Flint, Jr. : Physiology of Man, "Alimentation, Digestion, and Absorption," New York, 1871, p. 87.

blood and muscular tissue; and that, by the addition of extract of meat to our food, we neither economize carbon for the maintenance of the temperature, nor nitrogen for the sustenance of the organs of our body; and that therefore it cannot be called food, in the ordinary sense; but we thereby increase the working capabilities of the body and its capacity to resist injurious influences, *i. e.*, to maintain health under favorable circumstances." He further says that those constituents of the meat, which are soluble in boiling water, take no part in the formation and renovation of the muscular tissues, but by their effect on the nerves they exercise a most decided influence on the muscular work, wherein meat differs from all other animal and vegetable food. He therefore places extract of meat, and with it tea and coffee, under the head of "nervous food," in contradistinction to articles of "common food," which serve for the preservation of temperature and the restoration of the machine. But tea and extract of meat are of themselves incapable of supporting nutrition or maintaining life.[1]

But from the above it is evident that if the nutrient matter which has been hitherto thrown away, leaving in some instances little more than a watery solution of the alkaline salts, could be retained in some such way as to make it easily assimilable, the efficiency of these preparations would be greatly increased. This is in a measure accomplished in the preparation known as "beef-essence," as distinguished from "beef-tea," prepared from finely chopped pieces of lean meat, to which is added but a small quantity of water, while the whole is subjected in a closed vessel to the prolonged action of a water-bath. This results in a more or less complete comminution of the muscular fibre, which passes over with the salts and juices into the water, and, if the remaining meat be further compressed, perhaps most of the directly nutrient matter as well as the stimulating salts are obtained. The "beef-tea," so called, is more a watery solution of the salts with less of the tissue-forming material of the meat.

There has recently been introduced to the market a preparation known as Johnston's "Fluid Beef," which, if prepared as claimed, would seem to meet all the requirements of a concentrated food. The process is as follows: The beef is first treated so as to obtain the albumen and fibrin in a highly concentrated form; these nitrogenous compounds are then reduced to a powder capable of suspension in water, and added to "the extract of beef" carefully prepared. There results a paste, which is claimed to contain, and which must contain if the process described is carried out, all the constituents of beef. It is used diluted in water.

The Proper Daily Amount of Food.

The amount of food requisite to keep up a perfect state of the body depends so much upon circumstances of occupation, habit, climate, age, sex, etc., that the best guide is generally found in the information afforded

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[1] Northwestern Medical and Surgical Journal, October, 1873, from the London Medical Record, April 16, 1873.

by the sensations of the individual. It is the universal conclusion of all who have directed their attention to the subject, that the time to cease eating is that at which a feeling of comfortable satiety is reached. This, while it may be indescribable, is, nevertheless, not difficult of recognition; although there may still be an inclination to eat on account of pleasant sensations due to the agreeable flavor of the food, it should be resisted. At all times to eat until a sense of discomfort, caused by distention of the stomach, is reached, ultimately results in dyspepsia.

As guardians of the public health, however, medical men are frequently called upon for information with regard to the dietaries of such public institutions as hospitals, prisons, almshouses, etc., while the success of expeditions by land and sea depends as much, if not more, upon a proper supply of food, than upon any other element—less, however, in these days of rapid steam transit than in earlier times, when long voyages and expeditions were more common. Accordingly, much attention has been given to the subject of dietaries, and physiologists have sought to determine the proper daily quantity of food by experiment, by extended observation of the habits of communities and districts in which the people are engaged in different pursuits, and by estimating the sum of excreted matters, which must, of course, be compensated by a suitable supply of aliment.

From investigations in the former direction—experiment and observation—by Drs. Christison, Edw. Smith, and Lyon Playfair in England, Moleschott, Pettenkofer and Voit, and Liebig on the continent of Europe, Dr.Letheby[1] deduces the following average requirements:

Daily diets for	Nitrogenous.		Carbonaceous.		Carbon.		Nitrogen.	
	grms.	oz.	grms.	oz.	grms.	grs.	grms.	grs.
Idleness	75.66	(2.67)	555.64	(19.61)	= 147.25	(3,816)	11.66	(180)
Ordinary labor	129.23	(4.56)	828.66	(29.24)	= 368.41	(5,688)	19.89	(307)
Active labor	164.65	(5.81)	971.04	(34.97)	= 442.09	(6,823)	25.33	(391)

In estimating by the second method of inquiry, it must be borne in mind that the excreta are greatly influenced by the quantity and kind of food. It is well known that if the supply of food be diminished within limits, life is still perserved by a proportionate reduction of the excreta.

Examining the subject from this standpoint, we are early impressed with the amount of waste matter daily thrown off. Thus, Prof. Dalton[2] estimates the daily discharges from the body, including that from the pulmonary and cutaneous surfaces, as something more than 7 lbs. avoirdupois, or 3.171 kilogrms.

Dr. Edw. Smith considers that a healthy man, of average weight (150 lbs., or 67.95 kilogrms.), discharges from the lungs 242.8 grms. (8.57 oz.) carbon, which, added to the quantity discharged from the skin and bowels, is not less than 272.0 grms. daily, or 4 grms. per kilogrm. (9.6 oz. daily =

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[1] Letheby : On Food, New York, 1872, p. 108.

[2] Dalton : Human Physiology, 5th ed., Philadelphia, 1871, p. 100.

4200 grs., or 28 grs. per lb.) of the man's weight. During light labor it ranges from 272.0 grms. to 297.5 grms. (9.16 oz. to 10.5 oz.); and during hard work, from 354.2 grms. to 396.76 grms. (12.5 oz. to 14 oz.). Supposing the first figures to represent idleness, the second moderate exercise (routine work, and the last hard work, they represent 612.1 grms. (21.6 oz.), 660.5 grms. (23.63 oz.), and 892.7 grms. (31.5 oz.) of dry carbonaceous matter, calculated as starch, for the three degrees of activity respectively.

As to the amount of nitrogen excreted, the results are subject to considerable variation, which the most modern researches have shown to be dependent upon the kind of food rather than the degree of tissue metamorphosis. The same observer concludes that an average-sized man, performing routine work, secretes from 141.5 milligrms. to 177 milligrms. per kilogrm. (0.92 grs. to 1.4 grs. per lb.) weight, or 8.03 grms. to 13.6 grms. per 67.95 kilogrms. (135.9 grs. to 210 grs. per 150 lbs.); a fair average being 162 milligrms. per kilogrm., or 11.2 grms. per 67.95 kilogrms. (1.15 grs. per lb., or 173 grs. per 150 lbs.).

Adding the excretion of nitrogen in other forms than urea in the urine and that passed in the fæces, we may adopt for the total amounts the figures of Dr. Letheby as sufficiently correct—being 12.31 grms. (190 grs.) at rest, and 19.43 grms. (300 grs.) when at routine work, and append the following comparative table from the same author.[1]

		Nitrogenous food.		Carbonaceous food.		Nitrogen.		Carbon.	
		grms.	oz.	grms.	oz.	grms.	oz.	grms.	oz.
During idleness, as determined—	by dietaries......	75.66	(2.67)	555.64	(19.61)	= 11.66	(180)	147.25	(3816)
	by excretions....	78.78	(2.78)	612.14	(21.60)	= 12.11	(187)	272.06	(4199)
	Average.....	77.22	(2.73)	583 89	(20.60)	= 11.88	(184)	209.65	(4005)
Routine work (ordinary labor), as determined—	by dietaries......	129.23	(4.56)	828.26	(29.24)	= 19.89	(307)	368.54	(5688)
	by excretions....	124.39	(4.39)	689.67	(23.63)	= 19.18	(296)	304.14	(4694)
	Average.....	126.81	(4.48)	758.96	(26.44)	= 19.53	(302)	336.34	(5191)

The first of these averages is represented by .96 kilogrms. (2 lbs. 2 oz.) of bread, and the second by about 1.58 kilogrms. (3½ lbs.). Whence, too, it appears that the relation of the nitrogenous to the carbonaceous constituents of food should be as 1 to 6 or 6½, and the relation of nitrogen to carbon as 1 to 19; whereas in bread it is as 1 to 23, and in meat 1 to 10; showing, as already stated, that the former requires the addition of plastic matter, and the latter of respiratory. In milk the proportion of nitrogenous to carbonaceous constituents is as 1 to 3.6 (calculating butter as starch), and the proportion of nitrogen to carbon 1 to 13, doubtless the proportions required in the dietaries of children.

A very much more liberal allowance than this, however, should be adopted in actual practice. Dr. Edw. Smith says "that even in periods of idleness a man's daily food should not contain less than 278.61 grms.

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[1] Letheby: Op. cit., p. 110

(4300 grs.) of carbon and 12.96 grms. (200 grs.) of nitrogen; and a woman's at least 252.09 grms. (3900 grs.) of carbon with 11.66 grms. (180 grs.) of nitrogen—these being the proportions which in his opinion are necessary to avert starvation diseases: and they are represented in the case of a man's diet by 623.48 grms. (22 oz.) of carbonaceous food and 84.16 grms. (2.97 oz.) of nitrogenous."

Having given the proportion of carbonaceous and nitrogenous matter in different kinds of food, and knowing the requirements of an average-sized man, we may thence make up a dietary for a known number of men for a certain length of time. The following table, from Dr. Letheby's volume on Food, shows the quantity of different articles of diet which contain 84.16 grms. (2.97 oz.) of nitrogenous matter, and it also shows the proportion of carbonaceous matter associated in each.

DESCRIPTION OF FOOD.			Carbonaceous matter in it, as starch.[1]		Carbon in it.		
	Grammes.	Ounces.	Grammes.	Ounces.	Grammes.	Grains.	
Skim cheese	187.04	6.6	25.22	0.89	43.86	778	Carbon deficient.
White fish	464.81	16.4	33.72	1.19	54.36	836	
Lean meat	412.10	15.6	50.44	1.78	61.61	951	
Skim milk	2,002.82	74.2	210.56	7.43	132.76	2,049	
Peas	317.90	11.2	227.28	8.02	140.20	2,164	
New milk	2,051.81	72.4	302.95	10.69	173.84	2,683	
Oatmeal	668.82	23.6	521.73	18.41	264.68	4,184	
Bakers' bread	1,040.07	36.7	572.46	20.20	293.63	4,532	Carbon in excess.
Wheat flour	779.35	27.5	758.22	26.79	301.09	4,647	
Indian meal	759.51	26.8	647.28	22.84	326.36	5,046	
Rye meal	1,051.41	37.1	824.97	29.11	405.99	6,265	
Barley meal	1,334.81	47.1	964.18	38.02	518.15	7,997	
Rice	1,334.81	47.1	1,085.70	38.31	521.78	8,053	
Bacon	955.05	33.7	1,750.84	61.78	8,016.08	12,617	

Prof. Dalton, whose observations are based upon experiment rather than upon theory, has found that the entire quantity of food required during twenty-four hours, by a man in full health and taking free exercise, is very much more than the rest allowance of Dr. Edw. Smith. Prof. Dalton's quantities are as follows:[2]

Meat	453	grms.	(16	oz.	or	1 lb.	avoird.)
Bread	538.46	"	(19	"	"	1.19	")
Butter or fat	99.19	"	(3½	"	"	0.22	")
Water	1.54	litres	(52 fluid oz.			3.25	")

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[1] Although the fattening and respiratory power of starch, sugar, gum, and pectin are nearly the same, the power of fat is a little more than twice as great as that of sugar.

[2] Dalton, Prof. J. C., M.D.: Op. cit., p. 100.

Making over 1.132 kilogrms., or 1132 grms. (2½ lbs. or 40 oz. avoird.) of solid food and rather over 1.4 litres (three pints) of liquid food.

The quantity of water consumed in the free state is subject to great variations, much depending upon habit, while the water contained in the different solid articles of food is so variable that much modification is resultingly made in the amount in the free state. Indeed, the water contained in some food, as succulent vegetables, may be so abundant that no additional fluid is required.

A comparison of these quantities with the table above given will show that this allowance is considerably more liberal than the diet of rest of Dr. Smith, but considerably less than the diet of routine work.

Army and Navy Rations.

A British volunteer in camp, in September, 1871, received daily, according to Dr. Letheby,[1] 679 grms. (1½ lbs.) bread, or 453 grms. (1 lb.) biscuit; 339 grms. (¾ lb.) fresh meat, or 453 grms. (1 lb.) salt meat, or 226 grms. (½ lb.) preserved meat; 4.72 grms. (⅙ oz.) tea; 9.44 grms. (½ oz.) coffee; 56.68 grms. (2 oz.) sugar; 28.34 grms. (1 oz.) of salt; and a very small quantity of pepper. This, exclusive of tea and coffee, contains 16.14 grms. (270 grs.) nitrogen, and 305.24 grms. (4721 grs.) of carbon; which are equal to 686.8 grms. (24.27 oz.) of dry carbonaceous matter, calculated as starch, and 113.36 grms. (4 oz.) nitrogenous matter, containing 305.24 grms. (4721 grs.) carbon and 16.14 grms. (270 grs.) nitrogen.

The British sailor receives, according to Dr. Carpenter,[2] 878.5 to 991.9 grms. (31 to 35 oz.) of dry nutritious matter, of which 736.8 grms. (26 oz.) are vegetable and the remainder animal; and these contain 112.70 grms. (5 oz.) of nitrogenous matter and 283.4 grms. (10 oz.) of carbon, as does also, according to the same author, the ration of the British soldier. Playfair[3] gives about the same figures for the English sailor; but his soldier's war ration seems to be an average derived from the actual dietaries of European and American soldiers during recent wars, which is 153.3 grms. (5.41 oz.) of nitrogenous food, and 360.31 grms. (5561 grs. = 12.71 oz.) of carbon, or, estimated as starch, 665.42 grms. (23.48 oz.). The French soldier receives, according to Carpenter, 134.6 grms. (4¾ oz.) nitrogenous food and 340.08 grms. (12 oz.) carbonaceous; the French sailor, according to Playfair, 162.67 grms. (5.74 oz.) nitrogenous food and 372.10 grms. (13.13 oz.) carbon, or, estimated as starch, 756.67 grms. (26.70 oz.).

The daily ration of the United States soldier is, of bread or flour, 623.48 grms. (22 oz.); fresh or salt beef (or pork or bacon, 320.08 grms. (12 oz.)), 566.8 grms. (20 oz.); potatoes, three times a week, 453 grms.

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[1] Op. cit., p. 114.

[2] Carpenter, W. B., M.D.: Principles of Human Physiology, 7th Ed., London, 1869, p 83.

[3] Playfair in Letheby on Food, p. 115.

(16 oz.); rice, 45.4 grms. (1.6 oz.); coffee, 45.4 grms. (1.6 oz.); sugar, 68.01 grms. (2.4 oz.); beans, 29.57 grms. (0.64 gill); vinegar, 14.78 grms. (0.32 gill); salt, 7.39 grms. (0.16 gill). The bread, meat (considered as lean), and potatoes furnish, according to Letheby's table, 169.18 grms. (5.97 oz.) nitrogenous food, and 496.23 grms. (17.51 oz.) carbonaceous, calculated as starch; substituting 340.08 grms. (12 oz.) pork for the 566.8 grms. (20 oz.) fresh lean beef, we would have 92.95 grms. (3.28 oz.) nitrogenous food, and 860.96 grms. (30.38 oz.) carbonaceous, calculated as starch. When we add to the above the alimentary principles contained in the rice, beans, sugar, and coffee, it will be seen that the United States ration is far more liberal than that of other nations. So liberal is it that even in war the "company fund" derived in commutation for articles not consumed, when well managed, increases rapidly; and during our recent civil war the advantage of this liberality was shown, on the march, and in the hospital, in diminished fatigue and recovery from disease, as well as the power of warding off all ordinary affections, excepting those due to malaria.

Habit is known to have considerable influence upon the amount of food consumed, and the effect of climate has already been alluded to. The quantities consumed by the natives of extreme northern latitudes have long been subjects of wonder to the readers of arctic voyages. Captain Parry relates, in his "Arctic Voyages," an instance of a young Esquimaux, not full grown, who consumed, in less than twenty-four hours, 1.92 kilogrms. (4¼ lbs.) of the raw, frozen flesh of a sea-horse, the same quantity boiled, .789 kilogrm. (1¾ lbs.) bread, besides .591 litre (1¼ pints) of rich gravy soup, a tumbler of strong grog, three wineglasses of raw spirits, and 4.25 litres (9 pints) of water. According to Sir John Ross and Sir John Franklin, the daily ration of an Esquimaux is 9.06 kilogrms. (20 lbs.) of flesh and blubber; according to Dr. Hayes'[1] personal observation, it is from 340.08 to 9.06 kilogrms. (12 to 20 lbs.) meat, one-third of which is fat. The latter observer remarked the effect of the cold upon the appetite of his own party, particularly in a craving for fats. Some of their number were in the habit of drinking the contents of the oil-kettle with evident relish.

On the other hand, the small amounts which serve to sustain life, and, apparently, health, are equally wonderful. The instances of Cornaro, and Thomas Wood, the miller of Belaricoy, related by Dr. Carpenter,[2] are sufficiently striking. The former subsisted upon 340.08 grms. (12 oz.) a day, chiefly of vegetable matter, with 396.76 grms. (14 oz.) of light wine, for fifty-eight years. The latter sustained a remarkable degree of vigor, for upward of eighteen years, upon no other nutriment than 453 grms. (16 oz.) of flour (containing about 396.76 grms. (14 oz.) of dry solids), made into a pudding with water, no other liquid being taken. All instances of total abstinence from food for any length of time may be

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[1] Rauch: Psychology and Anthropology, 4th Edition, New York.

[2] Principles of Human Physiology, 7th Edition, London, 1869, p. 87.

put down as impositions. The most recent of these, that of the Welsh fasting girl, was thoroughly investigated, and found to be such.[1]

CERTAIN CONDITIONS AND DISEASES RESULTING FROM THE USE OF DEFECTIVE, DEFICIENT, EXCESSIVE, OR DISEASED FOOD.

The Effects of Partial and Total Deprivation of Food—Inanition.

Since inanition is insufficient alimentation, and starvation total deprivation of food, the results of both must be ultimately identical, being, in the former, only more slowly induced; in the latter, more rapidly. It is therefore impossible to consider them separately.

Although certain animals, as cats and rabbits (the latter, when fed on fresh green vegetables, never drink [2]), bear very well the absence of water, except what is contained in the food consumed by them, it is said to be demanded by most mammals more imperatively even than solid food;[3] at least it is said that animals will live longer if deprived of solid food, and allowed to drink freely, than if deprived of both food and drink. But Schuchhardt [4] has shown that, on total withdrawal of water, animals very soon decline to take solid food; while Bischoff, and Voit and Chossat have proven that, if totally deprived of solid food, they very soon decline to take water; so that it comes to the same thing whether one or both are withdrawn. Further, the results are the same, whether there be defect in quantity or quality.

Researches upon inanition have been made by Chossat [5] upon pigeons; Collard de Martigny,[6] Bischoff and Voit on dogs; and Bidder and Schmidt on cats; while the horrors of shipwreck and famine have served to complete a tolerably correct picture of its phenomena in man. The very first effect of diminished ingestion or defective quality of food is an adaptation of the organism to these by a proportionate lowering of its tissue-changes, and a resulting of falling off in excretion. Thence result lessened capacity of the tissues for operations of any kind, mental or physical, although there may not be as yet a reduction of weight. Very soon, however, this appears, accompanied by a decline in temperature, rate of pulse, and respiration. The loss in weight is not in direct proportion to the amount of food withdrawn, because of the diminished excretion referred to. On the other hand, the maximum loss occurs at the early part of the experiment, partly because of the discharge of the residue of aliment taken the day

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[1] See numerous communications, with regard to, in the Med. Times and Gazette, Vols. I. and II., 1869, and other contemporary English journals.

[2] Hermann: Grundriss der Physiologie, 1872, p. 203, note.

[3] Flint: Physiology of Man, volume on Alimentation, Digestion, and Absorption, p. 21.

[4] Hermann: Op. cit., p. 203.

[5] Chossat: Recherches expérimentales sur l'inanition, Paris, 1843.

[6] Collard de Martigny: Recherches expérimentales sur les effets de l'abstinence complète d'alimens solides et liquides, sur la composition et la quantité du sang et de la lymphe, Jour. de physiologie, 1828, Tome VIII., p. 152.

before, and diminishes progressively with the excretion; though sometimes, in Chossat's experiments, the maximum daily loss was toward the termination, but never at the middle. The lessened temperature, rate of pulse, and respiration are due to diminished oxidation. There is not a uniform diminution of the excreta in all instances. Thus, the herbivora, which naturally excrete much less urea, assume, in the course of starvation, first the rôle of carnivora. All animals, during starvation, become flesh-consumers, consuming their own tissues. Urea excretion in herbivora is therefore increased until it approaches that of carnivora, after which there is a diminution corresponding to the diminished tissue-change. In carnivora, the falling off in urea is sudden from the first, and the more so the greater the excretion of urea before starvation began. Later, however, it is slower and more regular, because then the "organic albumen" of the tissues is being consumed; whereas, in the beginning, it is the intermediate "circulating albumen," or that derived more directly from the last food (Voit).

The time at which death occurs in starvation is influenced by the condition of the animal as to *obesity* and its *age.* When an animal is fat, some time is required until it is reduced to the condition of one just sufficiently nourished. Thus, while Chossat found that the average duration of life of pigeons was a little more than ten days, two, which were unusually fat, lived respectively 16.79 and 20.42 days. The young of all animals resist death from starvation most feebly, while those of medium and adult age exhibit proportionately increased endurance. Young doves lived only until one-fourth of their body-weight had disappeared (3 days), while old birds lived until almost half had disappeared (13 days). Apart from the consideration just mentioned, Chossat found, in experiments upon birds, guinea-pigs, and rabbits, that death quite uniformly resulted when the loss of weight equalled four-tenths of the original weight. He found the average duration of life in birds 9.35 days, in guinea-pigs and rabbits, 99.9 days. In rabbits, according to Collard de Martigny, the duration of life was 10 to 12 days; in dogs, the results of Leuret and Lassaigne[1] point to an average of 30 to 35 days. In Chossat's experiments, the *influence of temperature* in temporarily renewing the vitality of starving animals was strikingly shown. When food and increased temperature were afforded, even when the latter had almost reached the point at which death occurs, they were able to digest food, and slowly but completely recovered. When, however, food alone was restored to them, they did not recover. Death usually occurred in doves when the temperature reached 30° F. (−1.11° C.)

The importance of these observations upon the lower animals cannot be overestimated, for their results are equally applicable to human beings, and, thus applied, enable us to explain many phenomena observed under circumstances of deficient alimentation in man.

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[1] Leuret et Lassaigne: Recherches physiologiques et chimiques pour servir à l'histoire de la digestion, Paris, 1825, p. 210.

The length of time during which human life continues without food is influenced by so many causes, as temperature, obesity, supply of water, etc., that it is only possible to state it approximately at from 5 to 8 days.

After a certain period of largely deficient or total deprivation of food, it has been found impossible, both in the case of man and in that of animals, to maintain life by a restoration of food, the digestive powers seeming to be so enfeebled that assimilation is no longer possible.

It has already been said that the effects of insufficient aliment are the same as those of total withdrawal of food, except that they are longer in producing the result. The same is true of the effects of an exclusive diet, where death ultimately results, of which sufficient evidence has already been adduced.[1] The entire loss is, however, much less than in starvation, for it is true that the fatty and albuminous food may, to a certain extent, substitute each other. If albuminous food be withdrawn, and a diet of fat and water, or of fat, carbohydrates, and water be substituted, there is loss of weight, but less than in total withdrawal; the excretion of urea is significantly diminished, corresponding to diminished ingestion of nitrogen and diminished oxidation of the nitrogenous tissues.

Marked constitutional effects are produced, however, only after some days. Parkes kept a strong man upon fat and starch, and found full vigor preserved for five days; in a man, in whom he reduced the amount of nitrogen one-half, full vigor was retained for seven days. If the abstention was prolonged, however, there was great loss of muscular strength, often mental debility, some feverish and dyspeptic symptoms; then followed anæmia and great prostration. In accordance with the above statement, the elimination of nitrogen in the form of urea greatly lessened, though it never ceased, while the uric acid diminished in less degree.[2] According to Hammond, if starch be largely supplied, the weight of the body does not lessen for seven or eight days.

If fat be withheld, but a food of carbohydrates with albumen permitted, there is no significant alteration in tissue-change. If the carbohydrates be also withheld, but albumen permitted, there is a decided increase in the excretion, and increased oxidation of the nitrogen-holding constituents, so that, for maintenance of life, more albuminous matter must be ingested. The effect of a deficiency of fat in an ordinary diet, in developing occasionally, at least, a scrofulous diathesis, has been alluded to.

An effect of insufficient or defective aliment, most important to medical men, remains to be noticed: it is the tendency which arises in those thus situated to contract the so-called zymotic diseases, as typhus and malarial fevers, hospital gangrene, camp diarrhœa, and dysentery. This is thought to be the reason why pestilence and famine go hand in hand. The observations of Dr. Joseph Jones upon the Federal prisoners confined in the stockade at Camp Sumter, Georgia, forms, as Dr. Flint[3] well says:

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[1] See page 184.

[2] Parkes: Practical Hygiene, 5th Ed., Philadelphia, 1878.

[3] Flint: Physiology of Man, volume on Alimentation, Digestion, Absorption, p. 37 a. f.

"the most complete scientific history of inanition ever written." The effects of the deficient diet, consisting daily of 151 grms. ($\frac{1}{3}$ lb.) bacon and 566 grms. ($1\frac{1}{4}$ lbs.) corn meal, and often less, in connection with the accumulation of large quantities of the most noisome filth in contracted space (30,000 were confined to a space of 27 acres), in the production of diarrhœa, dysentery, scurvy, and hospital gangrene, with the frightful mortality resulting (10,000 in less than seven months), are graphically portrayed, and form one of the most stirring chapters in the history of the late rebellion. It is interesting to note, however, that malarial and typhus fevers were rare.[1]

Parkes, on the other hand, says that under partial deprivation of albuminates (70 to 100 grs. nitrogen daily), while the body gradually lessens in activity, and passes into a more or less adynamic condition, which predisposes to all the specific diseases, *it is to malarious and typhous affections especially* that this predisposition exists. A similar disposition to pneumonia exists, and the course of some of these diseases, as typhoid fever, is modified, the latter running its course with less elevation of temperature and no excess of ureal secretion.[2]

The Results of an Excess of Food.

(See also page 185.)

These are not uniform. Most frequently dyspepsia results from the irritation of the undigested and therefore unabsorbed excess. Few persons have failed to observe some of the slighter degrees of such indigestion. Fermentation and decomposition result in the evolution of gases, the chief among which are carbonic acid, sulphuretted and carburetted hydrogen. These are eructated, and passed *per anum*. When larger amounts are ingested, to these symptoms succeed crapulous diarrhœa, caused by the irritation, and the partly digested and partly decomposed matter is gotten rid of. On the other hand, constipation sometimes results, and purgatives are necessary to accomplish this. Septic conditions, due to the absorption of decomposed food, are not common; and the furred tongue, fetid breath, nausea, and even feverishness, often seen, are more frequently due to the irritation of the undigested mass in the alimentary canal than its absorption. This same train of symptoms with concentrated urine, due to increased urea elimination, may, however, result from absorption of putrid food.

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[1] Investigations upon the Diseases of the Federal Prisoners confined in Camp Sumter, Andersonville, Ga., instituted with a view to illustrate chiefly the Origin and Causes of Hospital Gangrene, the Relations of Continued and Malarial Fevers, and the Pathology of Camp Diarrhœa and Dysentery, by Joseph Jones, M.D., Prof. of Medical Chemistry in the Medical College of Georgia, at Augusta, and formerly Surgeon in the Provisional Army of the Confederate States; in 3 vols., manuscript, Augusta, Ga., 1865–'66. For a full and admirable abstract see also Austin Flint's Physiology of Man, volume on Alimentation, Digestion, and Nutrition, p. 37 et seq., New York, 1871.

[2] Parkes: Op. cit., p. 204.

It is scarcely necessary to state that in most persons a moderate excess of food over the force-demands of the economy results in the laying on of an increased amount of fatty or adipose tissue, derived in part from the albumens of the food and partly from the oils and carbohydrates, while the nitrogen is eliminated in the urine in the shape of urea. Anything beyond such moderate excess of any of these three divisions of alimentary principles usually passes away in the fæces, with more or less of the symptoms of dyspepsia alluded to.

Although the facts, as stated in the last paragraph, cover a majority of instances, it is still possible for some one or more of the chief alimentary principles to be digested and absorbed in such quantity as to produce harmful results. This is probably more frequently the case when habit or necessity has caused the individual to use, as food, a large amount of one of these principles, to the exclusion of a proper proportion of the rest. Allusion has already been made (page 185) to the congestions of the liver and gouty diathesis, caused by an excess of albuminates. The experiments of Dr. Hammond[1] proved that albuminuria makes its appearance, sooner or later, after the adoption of an exclusive albuminous diet. An excess of albuminates also causes a more rapid oxidation of fat, while an excess of fat lessens the absorption of oxygen, and hinders the metamorphosis of both fat and albuminous tissues. (See also page 186 for some of the effects of an excessive proportion of fatty and farinaceous principles.)

Ergotism.[2]

Ergotism is the constitutional condition produced by the long-continued use of the ergot of rye (Claviceps purpurea), in the shape of bread and other preparations made of flour, derived from spurred rye or wheat, barley, rice, or other grains, upon which it develops in wet seasons, and in certain countries, as France, Switzerland, and Germany. Ergot-poisoning was very much more common many years ago, from the ninth to the eighteenth century, than at present. During that period epidemics devastating whole races of people were common, but of late years they have been very rare. The cause of ergotism was discovered in 1630 by Thuillier.

There are two forms of chronic ergot-poisoning: one characterized by the presence of convulsions with disturbance of sensation, and called spasmodic ergotism; the second by gangrene of the extremities and face, and is called gangrenous ergotism.

Spasmodic ergotism.—Of this the symptoms are, first, a peculiar irritation of the sensitive nerves of the skin, affecting chiefly the fingers and toes, and compared to that of the creeping of ants, which continues throughout the whole illness, and is the last to disappear; second, almost simultaneously,

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[1] Hammond: Experimental Researches, p. 20.

[2] We have nothing to do, in a treatise on Hygiene, with the so-called acute ergot-poisoning, a condition induced when large quantities of ergot are introduced into the economy for medication or other purposes.

symptoms of gastro-intestinal irritation, vomiting, purging, and colicky pains; third, insatiable hunger accompanying the vomiting and diarrhœa; fourth, the formication becomes very acute pain; fifth, a peculiar sensation of discomfort, anxiety, and weariness, giddiness; finally, involuntary twitchings at first in widely different groups of muscles, as the tongue and extremities, which soon pass into painful continuous contractions, especially affecting the flexors. This latter (the muscular cramp) lasts from half an hour to an hour or more, followed by a period of exhaustion, which is soon succeeded by another painful convulsion. There may be delirium with loss of sight or hearing. The pupils are usually contracted, sometimes distorted, the eyes fixed, the skin covered with cold perspiration, urine suppressed, while there is violent dysuria from spasm of the bladder. Pustules and boils sometimes appear upon the skin, while whitlows and other nutritional derangements make their appearance at different date; cardiac contractions are slow and feeble, and the arteries are constricted, containing little blood. Death may occur from cardiac paralysis, and is generally ushered in by convulsions or paralytic symptoms. The duration of the illness is from four to eight weeks or longer.

Gangrenous ergotism.—In gangrenous ergotism we first have more or less the same train of symptoms as those described in spasmodic. To these is superadded, sometimes from the third day to the fourth week, an erysipelatous redness in some peripheral locality, on the toes and feet; less frequently on the fingers, hands, ears, and nose. This is followed by blebs, with ichorous contents, which soon discharge and leave a gangrenous spot of varying size, whence dry gangrene is developed; although the moist variety may supervene in accordance with the amount of moisture. It may be confined to a finger or toe, or may involve the whole hand or foot. The disease sometimes stops short at the erysipelatous redness.

Pellagra is a disease which is thought to be due to a fungus which infests *maize* or Indian corn. It occurs particularly in Lombardy, and is characterized by a scaly and wrinkled condition of the skin, especially of those parts exposed to the air. The strength and mental faculties are affected, sensation is obtunded, and cramps and convulsions supervene, much as in ergotism.

Trichiniasis.

Trichiniasis is an acute febrile disease, in which the muscular system is infested with the *trichina spiralis*, an extremely fine, thread-like, round worm, with a still finer head, but more rounded hinder extremity. This worm lies partially coiled within the sarcolemma of the ultimate muscular fasciculus. The trichina exists in two forms, the muscle-trichina and the intestinal trichina. The latter is the mature sexual trichina, and is larger in size than the muscle-trichina, being, in the case of the male, $1\frac{1}{2}$ mm. ($\frac{1}{16}$ in.), and the female, 3 to 4 mm. ($\frac{1}{8}$ to $\frac{1}{6}$ in.) in length. The muscle-trichina, at its maximum size, is only .7 to 1 mm. ($\frac{1}{35}$ in.) long. The most important difference, however, exists in the fact that the former is in a state of complete sexual development, both male and female, and the latter is not. The latter is the larval state of the former.

Trichiniasis is produced in man by the ingestion of pork which is itself infested with muscle-trichina. This undeveloped trichina undergoes development as soon as it enters the human stomach, and in seven days after it is introduced the females give birth to numberless embryos, which are developed from eggs in its uterus. These embryos soon migrate and become located in the voluntary muscles by paths which are, as yet, disputed. It may be by perforation of the bowel into the submucous tissue, or even into the peritoneal cavity, and thence through the loose connec-

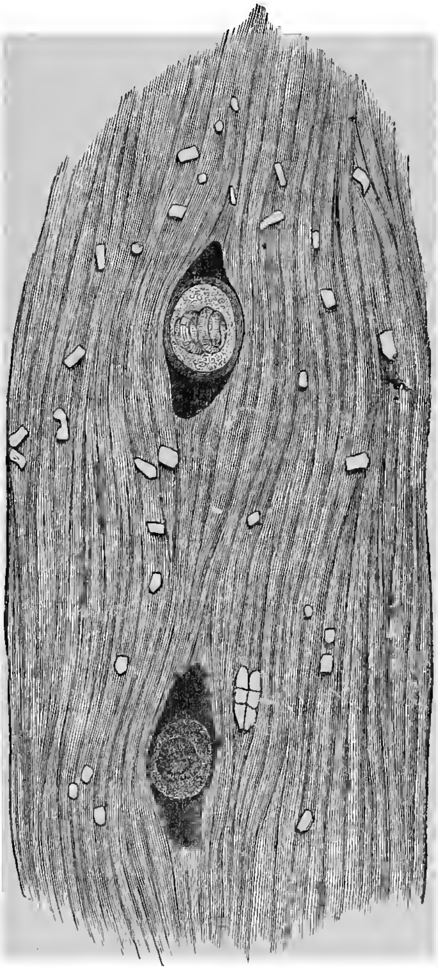

FIG. 7.
Capsulated muscle-trichinæ, with calcification of the capsules. (Magnified 80 diameters.) (After Heller.)

FIG 8.
Capsulated and calcified muscle-trichinæ. (Natural size.) (After Heller.)

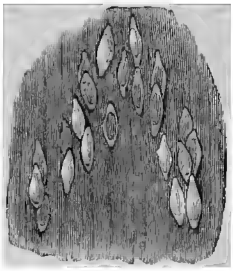

FIG. 9.
Capsulated and calcified muscle-trichinæ from the biceps muscle of a man. (Slightly magnified.) (After Heller.)

tive tissue into the mesentery and the retroperitoneal tissue to the muscles. Or it may be by the circulation. The former two are both likely routes, but the latter seems less likely, because, if it were the case, we should occasionally have the phenomena of embolism presenting themselves. But these are rare occurrences, and, when they occur, are attributable to other causes.

Having reached the muscles, the trichinæ perforate the sarcolemma and imbed themselves in the sarcous substance, where they grow for about fourteen days longer, when they have attained their maximum size as muscle-trichinæ. The sarcolemma around the worm enlarges, becomes thickened and lined with a layer of muscle nuclei, while above and below the capsule thus formed it atrophies and disappears. Thus the worm becomes encapsuled, and, partially coiled, is embedded in a mass of fine granules. The number thus encapsuled may be from one to four. Subsequently, lime salts are deposited in the capsule, and the worm becomes obscured and even hidden, although the capsule itself is thereby rendered more distinct and easily visible to the naked eye as small white dots or streaks, a millimetre in length. The appearance of the parasite at this stage, natural size, and slightly magnified, is well shown in Figs. 7 and 8. The appearance under a power of eighty diameters is shown in Fig 9.

The muscle-trichinæ thus encapsulated are not dead, but ready, on solution of the capsule by the gastric juice, to become developed into sexually mature intestinal trichinæ (requiring about two and a half days); they then copulate, and five days later the females give birth to living young, which are again ready to migrate to the muscles. The period during which the muscle-trichinæ remain susceptible of development, when placed under favorable conditions, is almost unlimited, except by the death of the individual in whom they reside, while the intestinal trichina rarely lives longer than from five to eight weeks.

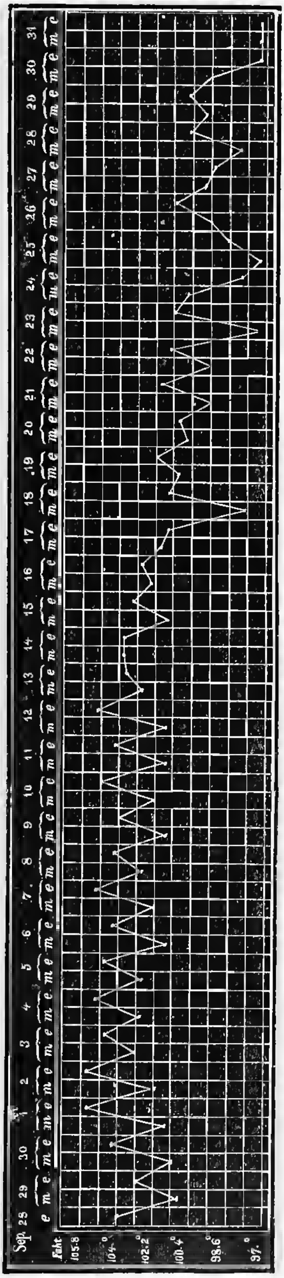

Fig. 10.

Fever curve of a severe case of trichinosis beginning about the tenth day of the disease. (After Friedreich, Deutsches Archiv f. klin. Med., IX., p. 460.)

Symptoms.—The symptoms of trichiniasis are by no means reliably the same, and although it is usual, for convenience in study, to divide them into three periods—1st, that of their introduction into the digestive tract; 2d, that of the migration of the embryos into muscle; and 3d, that of rest and capsulation—it is seldom possible to differentiate these stages by the symptoms. In all, except very light cases, there is fever, the curve in the temperature of which quite resembles that of typhoid fever, as shown in the accompanying diagram from Ziemssen's Cyclopædia (see previous page), with evening increment and morning decline, but still gradual ascent until the acme is reached, when there is again a gradual decline. The pulse ranges from 80 to 90, and thence to 100 and 120. There is also thirst. Occasionally only, a chill precedes.

The symptoms referable to the digestive tract, when present, are sensations of uneasiness, fulness, nausea, and occasional vomiting at variable periods, from a few hours to several days after ingestion of the infested meat. The appetite is capricious, being often great. There is more or less diarrhœa, which sometimes lasts for weeks, and may be followed by constipation. The trichinæ are very seldom found in the stools. Deglutition is sometimes painful from involvement of muscles employed in the act.

A very striking symptom is that of muscular soreness or lameness, which precedes the invasion of the muscles. Coincident with the latter, and not earlier than the ninth day, are observed also various degrees of hardness and swelling, accompanied by tenderness on pressure, together with muscular pain, which is often extreme, especially on motion. It is most marked during the fifth and sixth weeks.

As to symptoms connected with the nervous system, sleeplessness, apathy, and neuralgic pains are characteristic; also hyperæsthesia of the skin, in the form of pruritus or formication; sometimes undue dilatation of the pupil, and loss of hearing.

Œdema is almost always present, although sometimes so trifling as to be overlooked. Most constant and earliest is œdema of the eyelids and face, usually appearing about the seventh day, to disappear after from two to five days, sometimes to return. Œdema of the legs comes on later, about the ninth day, and is more marked and more permanent, although it may also disappear to reappear in a more marked degree. Changes in the composition of the blood, hoarseness, bronchial catarrh, hypostatic and catarrhal pneumonias, abortions in women, profuse sweats, eruptions, and bed-sores may occur. When death occurs, it is frequently due to imperfect respiration, because of the involvement of important muscles of respiration, as the diaphragm and muscles of the larynx. Notwithstanding these marked symptoms, a diagnosis is often difficult, and can only be certainly made by an examination of flesh removed by the harpoon or by excision. Despite also the seriousness of the malady, many cases of recovery occur even when the symptoms are most violent, especially in children.

Treatment.—There is no treatment for the disease when actually present, except the relief of the symptoms as they present themselves.

The only effectual treatment is the *preventive.* Although there is some difference of opinion as to the method in which the flesh of the hog becomes infested with the trichina, it is well determined that in man it arises only from the use of the flesh of the infected hog. As the worm is easily recognized, if not by the naked eye, by the aid of moderate magnifying powers, the most effectual mode of preventing the disease is by an official examination of all pork sold for food. In no other way can it be effectually excluded from market. A second measure of importance is the avoidance of the use of raw and partially cooked pork, and the application of high temperature in the cooking of pork. Trichinæ are effectually destroyed by a temperature of 142° to 155° F. (61° to 68° C.). Pork, therefore, should be thoroughly cooked before being eaten. These precautions being carried out, there is little or no danger of trichiniasis.

Tæniæ—Tape-Worms.

Tape-worm in man is acquired by the ingestion of the flesh of animals infested with the embryos of the worm. This embryo is known as *cysticercus cellulosæ.* Of the worm, there infest man, among others, two principal varieties—the tænia solium, or "armed tape-worm," and tænia saginata (mediocanellata of Küchenmeister), or "unarmed tape-worm." In the former, the head is provided with four suckers, and a central circlet of small hooks arranged in a double row; on the latter this coronet of hooklets is wanting. The cysticercus of tænia solium is found in the intermuscular connective tissue and other parts of the pig, in which animal it finds its place by the introduction with its food of links of tape-worm, which are crowded with eggs. This is easy of occurrence, on account of the well-known tendency of hogs to feed upon the fæcal evacuations of man wherever they may be found. It has also been found in the flesh of the dog, deer, and polar bear. The cysticercus of tænia saginata has been found only in the muscles and other tissues of the cow and giraffe, although it has been produced artificially in other ruminants, as the calf, goat, and sheep, by feeding with mature segments of the unarmed worm. But, although the worm is very common in man, in some countries, as Africa and Southern and Northern Germany, its cysticercus is very seldom found.

These cysticerci, or embryos, are developed in the stomachs of the animals in which they are found, from the mature eggs contained in the segments upon which they feed. The mature egg already contains an embryo—a delicate mass of protoplasm with three pairs of hooks. When these reach the stomach of the animal, the envelope is dissolved by the gastric juice, and the embryo set free. Thence it migrates, like the trichina, to the muscles, and soon becomes developed into the cysticercus. This is a thin-walled cyst, about as large as a pea, surrounded also by a capsule of connective tissue. Within the cyst, surrounded by a clear fluid, is a firm, white, roundish body, connected with a depression, easily visible on its external surface. In this body is found also a cyst, within which is the head of the cysticercus, inverted like the finger of a glove. This head is identical with that of the tape-worm, into which it may be later developed, whether tænia solium or saginata.

Fig. 11 shows the appearance of pork containing the cysticercus of tænia solium, and Figs. 12 and 13 the cysticercus itself—the former of natural size, the latter slightly magnified. The cysticercus of tænia saginata is not essentially different from that of tænia solium. It is somewhat smaller, and contains of course the head of the saginata. It is also much shorter lived than the tænia solium.

If now a portion of flesh containing either of these cysticerci is taken into the stomach of man, the embryo is speedily released from its cyst by solution of its envelope; it fastens itself by means of its suckers upon the intestinal wall, and is speedily developed into the tape-worm, by the addition of the segments of which its chief bulk is made up.

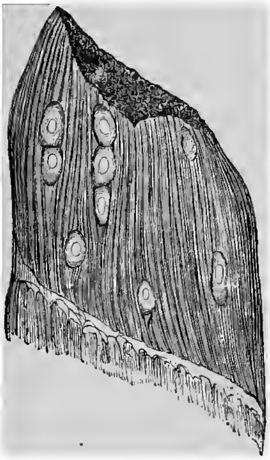

Fig. 11.
Pork containing the cysticercus of T. Solium.
(After Heller.)

Fig. 12.
Cysticercus cellulosæ (natural size).
(After Heller.)

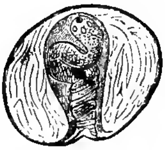

Fig. 13.
The same seen through a magnifying-glass.
(After Heller.)

The tænia solium is found only in the intestine of man, and is common in Europe and America, and especially the middle of Germany. The tænia saginata is also common in the intestine of man, and is prevalent in Asia, Africa, and Northern and Southern Germany. In Abyssinia almost every individual, beyond the nursing period, regardless of sex and age, is the subject of one.

The *curative treatment* of tape-worm is fully discussed in the works on the practice of medicine. We have here more particularly to do with its *prevention.*

The first essential condition of successful preventive treatment is official inspection, one and the same inspection serving for trichiniasis as well as for "measles," or cysticerci. Thus will the infected meat be excluded from sale. Secondly, no pork at least should be eaten without being thoroughly cooked. But there are other methods than by the ordinary use of food that tape-worm is acquired, which should be guarded against. Carelessness and uncleanliness on the part of those who have to do with the preparation and handling of raw meat often results in their infection in an accidental manner. Thus it is well known that it is a very common thing for persons employed in pork-packing establishments to have tape-worm. This may result from the accidental introduction of embryos into the mouth, as well as by the eating of pieces of raw pork, to which those thus employed are prone. For the same reason cooks are often subjects of tape-worm.

In the United States at least the flesh of ruminants used as food is so seldom the seat of its peculiar cysticercus, the saginata, that it is very rare for the worm to be acquired, although it is a common practice to eat meat rarely done, and it is considered that in this state it is more easily digested. It is not unlikely that the use of finely-grated raw beef, a therapeutic measure now often resorted to, may occasionally result in the production of tape-worm, and its preparation should not be without close inspection for the embryos, which are even more easily detected than those of trichinæ; and if all meat containing vesicles, white spots, or streaks, which are at all of uncertain nature, are rejected, there is little risk of acquiring tape-worm.

NOTE.—The cuts on pages 160 and 161, are camera-lucida drawings, made from actual specimens of the different flours as found in commerce, excepting that of the potato, which was drawn from a scraping of the tuber. The specimens were prepared by dusting on the glass slide a minute quantity of the flour and then moistening it with a drop of water.

ON DRINKING-WATER

AND

PUBLIC WATER-SUPPLIES.

BY

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ON DRINKING-WATER AND PUBLIC WATER-SUPPLIES.

INTRODUCTION.

THE importance of an abundant and good supply of water for domestic purposes is, at the present time, a subject which needs no discussion. For drinking and culinary purposes, for washing, for the rapid removal of the excreta, water of greater or less purity is required; but for all these purposes an abundant supply is needed, as well as in many cases for manufacturing industries, for the extinguishing of fire, for the sprinkling of streets, and, in rural communities, for the irrigation of grass and garden plats.

In spite of the magnitude of the water-works of the Romans, Greeks, and other ancient peoples, the aqueducts, the storage reservoirs, the public baths, and in spite of the lavishness of the supply for public uses and in the houses of the rich, it is probable that there has never been such general and widespread interest as there is to-day in the matter of water-supply *as a sanitary necessity*, not only to the community as a whole, but also to the individuals, no matter how poor, who make up the community.

In choosing the source from which the water-supply is to be taken, three prominent points demand consideration. In the first place, can the source in question furnish enough water; secondly, is the water of sufficiently good quality; thirdly, how does the cost of the construction and maintenance of the necessary works compare with the expense of obtaining water from other sources.

Quantity.

The question of available quantity is all-important. There are many instances on record where a supply of water has scarcely been introduced before it has proved insufficient in quantity. Such failures arise either from an over-estimate of the amount which the chosen source can furnish, or from an under-estimate of the needs of the city or town supplied. What shall be considered an abundant supply of water? This is a question which does not admit of answer from simple theoretical considerations. We may determine with tolerable accuracy the amount necessary, on the average, for each family for household purposes, or the amount required in certain manufacturing establishments for a given amount of finished product; but for many purposes it is very difficult to estimate, and the item of waste enters largely into the account. The following table, taken from Fanning's Water-Supply Engineering, gives the average daily supply of a number of American cities in the year 1874.

CITIES.	Total average daily supply.	Average daily supply per head.	
	In U. S. gallons.	U. S. gallons.	Litres.
Washington	18,000,000	138	522
New York	....	100(?)	378(?)
Detroit	9,013,350	87	329
Jersey City	10,421,001	86	326
Chicago	38,090,952	84	317
Worcester	3,000,000	80	303
Montreal	8,395,810	66	254
Charlestown	7,643,017	62	235
Boston	18,000,000	60	227
Buffalo	8,509,481	60	227
Philadelphia	42,111,730	58	219
Brooklyn	24,772,467	58	219
Salem	1,380,000	55	208
Cambridge	2,300,000	54	204
Cincinnati	13,600,596	45	170
Cleveland	5,625,150	45	170
Newark	4,732,718	38	144
Louisville	3,598,730	24	91

The following table is selected from Humber's Treatise on Water-Supply, but the amounts there given in English gallons are calculated into U. S. gallons and litres (in round numbers).

TOWNS FURNISHED WITH					
AN INTERMITTENT SUPPLY.			A CONSTANT SUPPLY.		
TOWN OR CITY.	Daily average supply per head, in		TOWN OR CITY.	Daily average supply per head, in	
	U. S. gallons.	Litres.		U. S. gallons.	Litres.
Windsor	56	210	Glasgow	63	240
Chester	55	207	Edinburgh	43	163
Birkenhead	51	194	Sheffield	35	132
London	48	181	Newcastle	34	127
Liverpool	29	109	Leeds	27	104
Hastings	25	95	Manchester	25	95
Bath	23	86	Bristol	22	84
St. Helen's	21	79	Norwich	17	65

The following table gives details with reference to the use of water in certain continental cities, and is selected from a large mass of information compiled by E. Grahn, civil engineer, at the instigation of the German society of "Gas- und Wasserfachmännern."[1]

CITIES.	Total daily amount in cubic metres.	Daily average supply per head in	
		Litres.	U. S. gallons.
Karlsruhe	12,000	581	154
Bonn	10,000	289	76
Hamburg	80,000	237	63
Dresden	45,000	228	60
Frankfurt a. M.	23,050	223	59
Cöln	27,000	200	53
Altenburg	3,632	163	43
Braunschweig	10,000	154	41
Bamberg	4,000	148	39
Kassel	6,200	124	33
Hannover	15,000	116	31
Altona	1,200	115	31
Leipzig	11,000	86	23
Ascherleben	900	52	14

For domestic and household uses, from 15 to 20 gallons per person per day is a sufficient allowance, but of course a much larger amount is used for manufacturing and mechanical purposes. Making allowance for this, for the fountains which are the usual accompaniments of water-works, for street-sprinkling, extinguishing fires, etc., we may regard an average of 60 gallons per day for each inhabitant as a very liberal provision. In the case of the smaller towns where no extensive manufactures are carried on, a much smaller amount than this may suffice. It is to be borne in mind, however, that the chosen source must be able, on occasion, to furnish an amount very greatly in excess of the average consumption. Thus, in Boston, in 1872, at the time of the "great fire" which burned over an area of about sixty acres of the business portion of the city, while the daily consumption was averaging 12,500,000 gallons, there were used by the fire department some 18,500,000 gallons in thirty-five hours, and the greater portion, in fact, during the first eighteen hours.[2] To provide for such emergencies as this, either the source must be abundant, or reservoirs must be provided for the storage of a quantity of water sufficient to meet such occasionally occurring abnormal demands.

Waste.—In all cities and towns supplied by public water-works, there is a very large amount of water actually wasted. The Chicago Board of

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[1] See Journal für Gasbeleuchtung und Wasserversorgung, Vol. XX., 1877.

[2] Report of the Cochituate Water Board to the City Council of Boston, for the year ending April 30, 1873. City Document, No. 103, p. 42.

Public Works, in their report of March 31, 1875, estimate that "one-half of the water now pumped is wasted," and in the St. Louis Report for 1876 a calculation is made by the engineer, Col. Henry Flad, by which it appears that the prospective cost to the city for a period of ten years, on account of waste, is over four million dollars.

There are two general methods suggested for lessening the waste which occurs. One is to introduce a rigid system of inspection to detect all leakage from the pipes and from imperfect fixtures, and to prevent all unlawful use of the water. Such a system has been found to work admirably in some places, a notable example being in Liverpool, England, where, by meters invented for the purpose, it was possible to determine the amount of water flowing in small sections of the pipes, and thus to locate any considerable leak or to ascertain where an abnormal amount of water was being used or wasted.[1] The second method is to supply all the water through meters, as is now done with that portion which is used by manufactories and other large establishments. The principal objection urged against the adoption of this method in the case of private families, is the fear that, by the use of meters, an economy of water would be effected among the very class of people where, for the general good of the community, it is important that water should be used freely. There is considerable weight to this objection and, if meters are to be introduced into the cities, either a certain amount of water must be allowed free, and the excess charged for at an established rate, or else some other arrangement must be made for the benefit of the poorer class, especially for persons and families living in tenement-houses. It is further to be said that the cheaper meters are not very reliable, and it is often possible to pass a considerable amount of water without its being registered, provided the water pass slowly. The question is, after all, one which must be settled by local considerations. In many places, where there is an abundance of water at command and where the rates are low, the expense and the attendant inconvenience would make it advisable not to introduce meters. In other localities, where the available water is limited in quantity, or where, without economy, the existing supply is likely to prove insufficient in the immediate future, or in places where the rates are of necessity high, the introduction of meters would be advisable. The waste in northern cities during the winter is enormous, as it is very common to leave the faucets open during the night, in order to prevent freezing. To remedy this waste it would not be impossible to insist that the service-pipes should be laid below the line of frost, and that in the houses it should be possible to shut off the water and drain the pipes whenever there is danger of freezing. Vigilant inspection would probably accomplish as much as the introduction of meters to check such waste.

Double supply.—In view of the difficulty which sometimes exists, of obtaining from a single source a sufficiently abundant supply of good

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[1] See the very valuable report of G. F. Deacon, Borough Engineer, reprinted in the Report of the Cochituate Water Board of the City of Boston, for the year ending April 30, 1874. City Document, No. 55, pages 84–112.

water to meet the wants of a large community, it has often been proposed to adopt a system of double supply, *i. e.*, to furnish water of two qualities. It is true that for many purposes, as for extinguishing fires and for sprinkling streets, a water would answer which would not be suitable for drinking, and such a supply might in many cases be easily procured, while to procure an abundance of water well suited for drinking would involve a large outlay. To the double system there is no objection, if the poorer water can be drawn only from street-hydrants, which are under municipal control; but it is not practicable to supply two sorts of water to private dwellings, with any security that the distinction between them will be regarded; no domestic, and indeed no average inhabitant, will fail to use for all purposes that water which is most handily obtained, unless, indeed, it be actually repulsive to the taste. In the case of large cities, it is seldom that a single source of sufficient size can be found, and it becomes a question to be settled by local considerations whether each portion of the supply shall be distributed to a different section of the city, or whether the water from all sources shall be united in a common reservoir or reservoirs, and distributed therefrom. The city of London is supplied by eight companies, of which five take water from different points on the Thames. Here each company supplies a certain district. In cities where the entire works are under control of the same authority, it is not uncommon to unite the waters coming from the different sources, unless they are of decidedly different character.

Intermittent supply.—In many places in the Old World, especially in England, the supply of water is intermittent, *i. e.*, is let into the distributing pipes for a certain number of hours only during the day. This method is open to so many and such obvious objections that it has never been introduced to any extent in this country, and has fallen into disfavor abroad.

Quality.

We shall now consider, in a general way, the qualifications which must be possessed by a water in order to be considered sufficiently good for domestic use. Many of the questions which will naturally arise in this connection will be discussed more appropriately hereafter, when we come to consider the various sources to which we must look for our water-supply.

In the first place, absolute chemical purity, in the sense of freedom from all foreign substances, is neither possible nor desirable. The surface-waters of uninhabited granitic and gneissic regions are often very free from foreign matters; but even they, in their passage through the air and over the ground, dissolve gaseous and solid substances. Most of the mineral substances which make up the earth's crust are either more or less soluble in water, or are decomposed by water with the production of soluble substances. The more common mineral substances thus occurring in natural water are the chlorides, sulphates and carbonates of sodium, potassium, magnesium, and calcium, together with silica, alumina, and iron, in some form of combination.[1] Organic matter of animal or vegetable origin also occurs in most waters; it is various in character, and of very diverse sanitary importance.

Within reasonable limits, the presence of a greater or less amount of dissolved mineral matter is of little account so far as the wholesomeness of the water is concerned. It is well known that freshly distilled water is quite unpalatable; this is due in part to the absence of dissolved gases which occur in almost all natural waters, and in part to the absence of mineral salts.[2] Most persons, guided by taste alone, would prefer a water containing a moderate amount of matter in solution, and a water may be somewhat highly charged with mineral salts without being unsuited for drinking. For certain special manufacturing operations water of peculiar character is required, or, at least, water which is free from particular substances, while other substances, although present in considerable quantity, are of indifference. The salts which give the most trouble are the compounds of lime and magnesia, especially the carbonates and sulphates.[3]

These compounds give rise to the incrustations which form in steam-boilers (see farther, page 286), and their presence causes the water to be "hard." The practical disadvantages of a hard water for boiler use and for washing are very great; but a water which is tolerably hard may be used to drink without inconvenience. In fact, many maintain that a hard water is more wholesome than a soft water. Some years ago Dr. Letheby tabulated statistics from some sixty-five English towns, with reference to a possible connection between the hardness of the water used and the death-rate. In this table the towns using the hardest water had the lowest death-rate. From this statement improper inferences have been drawn. Such a comparison cannot be otherwise than fallacious, for the death-rate depends upon so many factors that it is impossible to say how far it is affected by the water-supply, if, indeed, it is affected at all. Moreover, some of the towns

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[1] Where the amount of dissolved substances is considerable, the water is generally called a "mineral water." These waters, which, as a rule, come from a considerable depth in the earth's crust, often contain, in considerable quantities, substances which occur either not at all or only in minute quantities in ordinary waters, such as would be considered available for water-supply.

[2] On shipboard the water is aërated and sometimes filtered through animal charcoal or other substances before being used to drink; it has been proposed to render it more palatable and more wholesome by the addition of a certain amount of mineral salts. A mixture which has been suggested for this purpose consists, for 1,000 litres of water, of 4.8 grms. salt, 3.4 grms. sulphate of soda, 48 grms. bicarbonate of lime [? W. R. N.], 14 grms. carbonate of soda, and 6 grms. carbonate of magnesia. It is stated that the Russian navy has adopted this idea, and furnished to its vessels a mixture of this character. *Fonssagrives: Hygiène et assainissement des villes, Paris,* 1874, *p.* 316.

[3] It is the more modern practice to speak of carbonate of *calcium* and sulphate of *calcium* instead of carbonate of *lime* and sulphate of *lime.* The modern practice is the better from a chemical point of view, but the older terms are still the more common in the world at large.

instanced as using soft water were towns where other sanitary conditions were notoriously bad, and some of those using hard water were well sewered and otherwise in a good sanitary condition. It should be said that Dr. Letheby himself, while strongly favoring moderately hard water, did not claim to show more by these figures than that "there is no evidence that soft water so benefits the health of the people as to reduce the death-rate." He also admits frankly that the water may have nothing to do with it. The question is an open one, but it can hardly be a matter of indifference whether the hardness of the water is caused by carbonate of lime or by sulphate of lime. Indeed, water containing a considerable amount of sulphate of lime is generally held to be injurious, while carbonate of lime is tolerated in much larger quantities; moreover, the compounds of magnesia are not to be regarded as having precisely the same effect as the compounds of lime, and the drinking of hard water containing a large amount of magnesium compounds is one of a number of things which have been assigned by different observers as causes of the "goître" which prevails in various localities. It is to be borne in mind that the human system has great power of accommodation. Thus, it sometimes happens that no ill effect is noticed from the habitual use of a hard water by natives, while strangers who come from a soft water district are quite sure to be affected. On the other hand, a person who has always used hard water may be seriously affected by undertaking to drink a soft surface-water. In this latter case it is to be said that, in addition to being soft, such waters almost always contain more or less vegetable matter, which may be, and probably is, the cause of the trouble.

Further, although there may be an open question as to the effect of drinking hard water, there is no question but that, on other sanitary grounds, soft water is much to be preferred, and especially with reference to cleanliness of person and of surroundings. Hard water is not only less agreeable in washing, but is less effectual as a cleansing agent. A portion of the soap used is destroyed for all practical purposes, and forms in the water an insoluble curd, useless as a detergent and unsightly to the eyes of those who are accustomed to soft water. For cooking, hard water is, as a rule, much less suited than soft, and if, in addition to these considerations, we take into account the fact that for most manufacturing operations soft water is desirable, it is evident that, for the general purpose of town-supply, soft water is to be preferred.

Besides mineral substances which we have discussed, all natural waters contain more or less organic matter in solution. This is due mainly to the action of the water on the decaying animal or vegetable substances contained in the ground over or through which the water drains, or to organisms which live and die in the water itself. A water entirely free from organic matter is very rare, although some classes of waters are much more liable than others to be charged with it. Surface-water, such as that of rivers and ponds, is apt to contain a good deal of dissolved organic matter, while springs and deep wells, or even properly protected shallow wells, often furnish water quite free from organic substances. The influence of such substances depends very much upon their source and nature. Thus, a water may be highly colored from the presence of peaty matter, or may taste quite decidedly of the smaller algæ, without being as far as we know unwholesome. It is well known that the water of the "Dismal Swamp," although strongly colored by dissolved vegetable matter, is held in high repute as a drinking-water, and is in especial favor for provisioning ships. It is true also that the waters of some northern streams, which contain a good deal of vegetable matter, are in repute for the same purpose. On the other hand, water draining from marshes, especially in hot climates, is known to be the cause of intestinal disorders; it is also suspected of causing malarial and other fevers, although some consider the air to be the sole agent in the latter cases. With reference to the effect of the lower orders of vegetable growth, especially of the minute fresh-water algæ, something will be said when we consider lakes as a source of supply, since lakes and ponds, natural and artificial, are particularly subject to such growths.

As a general rule, it is not difficult to decide whether a natural uncontaminated water is or is not suitable for general use. With reference to most of the substances which occur naturally in potable water, it is hardly fair to designate them as "impurities," because these substances are common to all natural waters and there is more or less of stigma conveyed in the term "impurity." Fairly to be designated as impurities, however, are mineral substances of known poisonous character and the organic matter of animal or vegetable origin which come as refuse from manufacturing or from household operations. A water which is chosen as a supply for towns or for individual families must be known to be free from all poisonous or deleterious mineral substances. This point is one that is readily settled by chemical analysis; but, as a rule, it can be done equally well by an inspection of the locality from which the water is to be taken, and its surroundings. The supply chosen must also be capable of being protected from all such injury in the future.

Pollution of drinking-water.—We come now to the consideration of the pollution of water by organic matters, and here we approach a subject which has occasioned much discussion, and with regard to which diametrically opposite views are held.

It is a universal belief that there is some connection between filth and certain forms of disease. By filth we understand decaying organic matter of animal or vegetable origin, and the chief point of difference in belief is as to whether the filth can originate specific disorders, or whether it simply forms a nidus for the growth and development of a something by which the disease is propagated. Whatever view is held on this point, provided the connection is admitted, the question next arises as to the vehicle by which this disease-producing something is carried, and it is held by most non-medical sanitarians as well as by many eminent medical authorities, that the air we breathe and the water we drink may both serve as agents in this matter; on the other hand, there are some who deny that there is, as a rule, any direct connection between disease and drinking-water, and who assert that a water which is not polluted to such an extent as to inspire disgust by taste or smell is fit to drink.[1] Those who favor the former view call attention to the many recorded instances of sickness affecting individuals and families where the sickness has been coincident with the use of a polluted drinking-water; there are also cases recorded by competent observers where a zymotic disease has affected an entire community, and has been apparently on the increase, but has been checked by a change of drinking-water; there are other cases on record where the change to a better water-supply has in succeeding years been followed by a decrease in the average sickness, or by a decreased death-rate. In other cases still, a locality peculiarly liable to certain forms of sickness at periodic or accidental intervals, has ceased to be thus afflicted, even when surrounding localities have been visited as usual, and when no other conditions have been altered except that a polluted water-supply has been exchanged for one unpolluted or less impure. On the other hand, those who deny the "drinking-water theory" hold that such apparent connection between polluted water and disease is simply a matter of coincidence, and they point to the numerous instances where water known to be badly polluted has been used regularly for years with apparent impunity.

With all due allowance for imperfect observation and for prejudiced observers, it seems that at present the weight of evidence and of authority favors the idea that the drinking-water may become the cause of disease; and in drinking a polluted water one always runs more or less risk. In studying matters like this we can hardly expect to reach absolute certainty, unless possibly by means of direct experiments upon living human beings—a mode of investigation which we are involuntarily obliged to witness to a certain extent, and from which such data as we have are derived, but which we can never systematically conduct. No doubt there is much that we may hope to learn, in the future, with reference to the propagation of disease; but there are many things that must rest more or less on circumstantial evidence, and in determining principles which are to guide the community it is best to err on the side of safety.

The attempt to isolate the effects of various habits, which, from a hygienic standpoint, are decidedly bad, gives rise to problems which it is often impossible to solve. We know that there are many persons who live and seem to get along very well in utter disregard of the laws of health, as far as personal cleanliness, wholesome diet, pure air, and many other things are concerned; but, because many thus live for a time without experiencing evident inconvenience, does any one argue that purity of air, a healthful diet, and cleanliness of person are not to be recommended and desired? The effect upon the community of the bolting of indigestible food must be immense; but comparatively few are the acknowledged cases of injurious effects. We are able, however, in many cases, to show even in these matters that the apparent strength and im-

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[1] See especially Nägeli, Die niederen Pilze, München, 1877.

munity from discomfort is due to a constitution naturally strong, and the draft upon the vital energy may be seen, if not in the persons themselves in later years, at least in their children.

With reference to the danger from the presence of decaying organic matter in the drinking-water, we must distinguish between the organic matters from different sources. First in importance, no doubt, is excremental matter from human sources. The evidence seems very strong that the dejections of persons who are sick with certain particular diseases may communicate the disease to others if they are taken into the stomach. I do not know that there is any proof that *fresh* sewage from healthy persons, when largely diluted, is injurious if drunk. We know that fish sometimes gather about the mouths of sewers, and seem to thrive; we know, however, that *decomposing* sewage drives away the fish, and, with our present light, we can hardly fail to believe that decomposing excremental matter, even if it contain no specific organic poison, is detrimental to health when taken into the stomachs of human beings.

Next in importance to excremental matter is animal refuse, such as forms the waste from slaughter-houses, wool-pulling establishments, tanneries, etc. In the case of such substances, we have less conclusive evidence of direct effect upon health than in the case of excremental matter; and yet the suspicions against them are so strong that all possible means should be taken to keep them out of the sources of drinking-water.

Last in order of importance is matter which is purely of vegetable origin. It is felt that such substances, in their decay, may contaminate the surrounding air so as to be a source of injury to health, and it would certainly be undesirable to have any considerable amount present in a drinking-water. It is difficult to see why the products of the decay of all vegetable matters should be innocuous, if the products of the decay of animal matters are injurious ; and, in any case of contamination, animal and vegetable substances are associated together and it is impossible to distinguish, with absolute certainty, differences in their action or to say to which of them ill effects are to be ascribed.

In considering the conditions which a water must satisfy in order to be regarded as suitable for domestic supply, it must be borne in mind that a large portion of the water-drinkers in any large town or city are women and children, many of them living much of the time indoors, in an artificial atmosphere, and they are thus peculiarly sensitive to the action of influences which would be without effect upon a healthy person spending a reasonable time in the open air. Moreover, in the choice of a water-supply, we must not only avoid a source which contains actually poisonous substances or substances which are suspected with any considerable show of reason of being injurious to health ; we must also consider, to a certain extent, some things which appeal mainly to the imagination. For this reason, a water should be as free as possible from color, although the coloring substance may be innocuous. It may be possible to educate a person or a community to drink a water that is strongly colored, but unless natural prejudice were overcome by education or by a life-experience, the average of mankind would turn from an unpolluted water colored yellow or brown by peaty matter, to the colorless, sparkling water drawn from a polluted spring, provided the pollution was marked by no peculiar taste or odor. The same thing is true of suspended matters. We have had in mind hitherto those substances which were actually dissolved in the water. Of course, much that has been said will apply as well to matter held in suspension; this is true especially of excremental matter and of substances of animal origin. There are many substances of earthy origin which occur, especially in surface waters, which are not capable of being dissolved, and which, unless taken in excessive quantities, are of comparatively little sanitary importance. Still even such mineral substances as clay and mica,[1] when constantly present in the drinking-water, have been regarded as the cause of diarrhœa and other forms of sickness. Nearly all waters that carry such suspended mineral substances carry also a quantity of vegetable matter in suspension or in solution, and just how far each sort of impurity is to blame for ill effects it is impossible to say.

Now it is possible to educate a person into drinking without hesitation a turbid water, and in some localities where all the soft waters are turbid and the clear waters hard and unfit to drink, turbidity becomes even a recommendation. As a rule, however, any suspended matter renders the water less desirable to drink, and, in the choice of a supply, the preference should be given to a clear water, or if turbidity is the only disadvantage which a water possesses, the water should be freed from suspended substances by a process of filtration.

Again, from the standpoint of the imagination, even if it proves that the generally received idea is incorrect, and that there is no real danger to be apprehended from the use of polluted water, we should still endeavor to reach the greatest possible purity. Although, as has been said before, there is no proof that water containing perfectly fresh sewage is unwholesome if drunk, still, scarcely any one would be willing to drink such water, and, as a mere yielding to what is certainly a reasonable prejudice, we should strive for the greatest possible freedom from contamination.

In Europe, and especially on the continent, great stress is laid upon the temperature of the water, and some go even so far as to reject rivers from the list of available sources on account of the considerable variation in temperature to which the water is subject at different seasons of the year. We cannot, however, in this country go so far, although it is very true that a uniform temperature is desirable. Over a large part of the country ice is used almost universally in summer. In all the Northern States, a supply of ice sufficient for the summer's consumption can be readily stored during the winter, and even in the southern cities ice is not extravagantly dear, and for most purposes other than for drinking the matter of temperature is of little consequence.

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[1] For examples see Parkes's Hygiene, 4th Ed., p. 38.

The Question of Cost.

There comes a time in the history of almost every growing community, when a supply of water must be obtained; but, although in theory it may be true that the *best* water should always be introduced regardless of expense, in practice this rule cannot be insisted upon; and if, in the case of a given town, a supply of *good* water can be obtained at a reasonable expense, while the cost of introducing the best water accessible would be such as to prevent the introduction of any water at all for years, it is manifestly better, from a sanitary point of view, that the less desirable source should be chosen. It is a question, however, whether sometimes there might not be co-operation on the part of several villages or small towns, so as to make available for all a source which, on account of distance or for other reasons, would require a larger outlay than could be borne by one alone. Small communities have always profited to some extent by the works carried out by larger cities, but the examples of co-operation by the association of a number of small communities are not so common. An instructive example is afforded by the means taken to supply with potable water a district in the kingdom of Würtemberg.[1] This district, which is known as the "*rauhe Alb*," lies from 750 to 800 metres above the level of the sea, and some 300 metres above the surrounding lowlands, has a width of some 33 kilometres, and is of such a geological character that the rainfall quickly disappears in the clefts of the limestone or dolomitic rock, and does not appear again in springs within the region. The surface- and rain-water, collected by the inhabitants in cisterns and in puddled cavities in the ground, was not only inferior in quality, but so insufficient in quantity that often in cold or dry weather it was necessary to bring water from the valley below, a distance of from 2 to 12 kilometres.

The plans for supplying this district, containing between sixty or seventy villages, with some 40,000 inhabitants scattered over an area of twenty-two square miles, were devised by Dr. v. Ehmann, State Director of Public Water-Supply.

The villages are divided into nine groups, each group forming a unit for purposes of water-supply. The water is taken partly from natural springs in the lower land, and partly from the ground-water by means of wells and galleries, and is pumped by water-power to the plateau above.

The height to which the water has to be forced in order to reach the various distributing reservoirs, as well as other details, may be learned from the following table:

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[1] Das öffentliche Wasser-Versorgungswesen im Königreich Württemberg. Denkschrift aus Anlass der internationalen Ausstellung für Gesundheitspflege und Rettungswesen in Brüssel, verfasst von Oberbaurath v. Ehmann, Stuttgart, 1876, 4to, pp. 137. This work, being printed for private distribution only, is not readily obtained. Abstracts are to be found in the Correspondenzblatt des niederrheinischen Vereins für öff. Gesundheitspflege, vi. (1877), p. 99, in Grahn's städtische Wasserversorgung, i., pp. 4–9, and in the Journal of the Franklin Institute, January, 1879.

Group.	No. of communities.	Total inhabitants.	Amt. of water in cubic metres per day.	Height to which water is lifted in metres.	Length of mains in metres.	Source of water.
I..........	9	7,525	600	265	34,000	Springs.
II.........	8	7,600	570	300	50,000	Ground-water.
III........	8	3,600	270	180–255	30,000	Ground-water.
IV........	8	3,700	280	117–200	32,000	Springs.
V.........	9	3,800	280	320	50,000	?
VI........	7	1,700	130	180	28,000	Springs.
VII.......	9	2,000	170	220–230	30,000	Springs.
VIII.......	6	4,300	300	200		
IX........	4	2,900	200	173–230	25,000	Springs.

It will be readily seen that, in this case, it would be impossible for a single village, with from 400 to 800 inhabitants, to provide the means for the erection and maintenance of the works necessary to bring the water from such a distance; and indeed, besides bearing the expense of the preliminary surveys, of the preparation of plans, and of the superintendence of the work, the State contributed in some cases 25 per cent. of the cost of construction. Of course, we shall not find in our country any locality where the condition of things is precisely similar to that which has just been detailed; but the idea of co-operation and of a comprehensive plan for supplying a district defined by natural conditions, rather than one bounded by accidental political circumstances, is worthy of consideration.

The conclusions thus far reached are that a suitable source of supply should furnish water which is abundant in quantity; the water should be colorless and clear, *i. e.*, free from all turbidity; it should be soft and contain not too large an amount of mineral matter in solution; it should contain no excremental or other animal matter; and it should be so situated as to make it possible to protect it from defilement in the future. Moreover, while the imagination as well as the reason is to be consulted in the choice of a supply, an extravagant outlay is not justified when called for by extravagant demands for excellence.

With these general conclusions, we shall proceed in the next section to consider the various sources of water-supply which are available, with their advantages and disadvantages.

SOURCES OF SUPPLY.

It would be very difficult to devise a scheme which should enable us to classify the various natural waters, and to separate the classes by strict lines of demarcation, For convenience, however, and with especial reference to the subject in hand, all waters used for purposes of town or household supply may be considered under four general divisions, as follows:

1. Rain-water.
2. Surface-waters, including streams and lakes.
3. Ground-water, including many shallow wells and a few springs.
4. Deep-seated water, including deep wells, artesian wells, and most springs

In the case of some artesian wells, the water now supplied may come from the still unexhausted deposits made long before man appeared on the earth; but, with such exceptions, all the water used for town or household supply comes more or less directly from that which falls from the atmosphere, as rain or snow.

The course of the rain when it reaches the earth, after its passage through the atmosphere, depends, in great measure, upon the character of the surface upon which it falls. If the region is rocky, the water may find its way, by means of torrents and small brooks, directly into the open watercourses, or into ponds; or, if the rain falls upon the outcrop of inclined strata, it may sink through seams and fissures of the rock, and disappear from the surface to accumulate in some lower stratum, or to form underground streams, which may appear again to the light in less elevated regions. If the ground is sandy and gravelly in character, the water soaks readily into it, and, if the underlying stratum is impervious, collects to form the ground-water of the locality. This ground-water, as will appear more fully hereafter, is generally in motion toward a lower level, and may emerge as actual springs of small volume, or may issue, unobserved, to swell the volume of rivers and ponds.

On Rain-water as a Source of Supply.

It is not likely that propositions will be seriously entertained in this country to supply by municipal enterprise any town or city with water collected directly as it falls from the clouds. Plans to this end have, it is true, been proposed,[1] but it would be impossible in this way to collect enough water to supply more than what would be necessary for drinking and for culinary purposes, and the disadvantages of a double system of water-supply have already been spoken of. There are regions, however, in this and in other countries, where the main dependence of the inhabitants for the water used in the household is, of necessity, the rain-water collected and stored in some sort of tanks or cisterns. Where this is necessary, it is usual for the individual householder to secure his own supply by collecting the rain (and snow) which falls upon his own premises. A house 40 feet by 20 feet, *i. e.*, covering 800 square feet, would receive upon its roof, with a rainfall of 42 inches, 2,800 cubic feet of water in the course of the year. This would be about 21,000 gallons, or about 60 gallons per day on the average.

The rain-water which falls in the open country, away from manufactur-

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[1] Ormsby, A. S.: A New Idea for the Water-supply of Towns, etc., pamphlet, pp. 42, London, 1867.

ing centres, is quite pure, and, no doubt, wholesome, although some regard the absence of mineral salts as a disadvantage. Rain-water, however, as ordinarily collected, often contains as much solid matter in solution as the waters of some of the ponds or lakes which are used as sources of supply. The Rivers Pollution Commission in England examined a large number of samples of rain collected at the experimental farm of Messrs. Lawes and Gilbert, about twenty-five miles from London. The average amount of dissolved solid matter in some seventy specimens was very nearly 4 parts in 100,000, although on one occasion as little as 0.62 part in 100,000 was found. The rain which falls in towns is more impure, as, in its passage to the ground, it takes up from the air both gaseous and solid substances. Moreover, as usually collected from the roofs of houses, it becomes contaminated with various objectionable substances, such as the dust of the street and the excrement of birds. The greater amount of the impurity in the air and on the collecting surfaces is washed away by the first portion of the rain, and it has been proposed to arrange the spouts so as to allow the first portion of water falling to run to waste. Devices to accomplish this object have been invented, and it is said that in Cadiz[1] the water conductors of each house are furnished with an arrangement to accomplish this object. As they are not automatic, it is safe to suppose that, in spite of these devices, a good deal of dirty water is collected—unless Cadiz is very different from the rest of the world.

Owing to the fact that rain-water is extremely soft, it will probably always be collected for washing, except when the general water-supply is also very soft. If it is to be used for drinking, especial care should be taken in storing it, and it should, as a rule, be filtered. Many examinations have shown that, as rain-water is usually stored, it is subject to contamination in a variety of ways. Open cisterns built in cellars are certain to collect dust and insects, and occasionally rats and mice; wooden cisterns, sometimes wet and sometimes dry, are subject to decay, and to vegetable growth; lead-lined tanks give up to the water metallic poison. For the storage of water in small quantity, there is nothing better, from a sanitary point of view, than slate tanks, and no objection can be offered to iron tanks protected from rusting by a coal-tar paint. The small storage-tanks will usually be situated at the top of the house, in order that the water may be delivered by gravity to the various apartments. Being used to supply water for flushing the water-closets, these tanks are sometimes in communication with the drains of the house, and instances are on record where the water had been rendered impure by the gases from the soil-pipes. The main bulk of the rain-water collected on the roofs of the houses is usually stored in underground cisterns built of brick laid in cement. These underground cisterns are unobjectionable, provided they are properly protected and are so constructed as to admit of ready cleaning.

It may not here be out of place to allude to the method of collecting and storing rain-water in the peculiarly situated city of Venice.

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[1] Ferreira: Hydrologie générale, Paris, 1867, p. 128.

The situation of the city prohibits the construction of ordinary wells, although of late years a number of artesian wells have been sunk. The cisterns have always been an important source of supply; these are constructed as shown in Fig. 1.

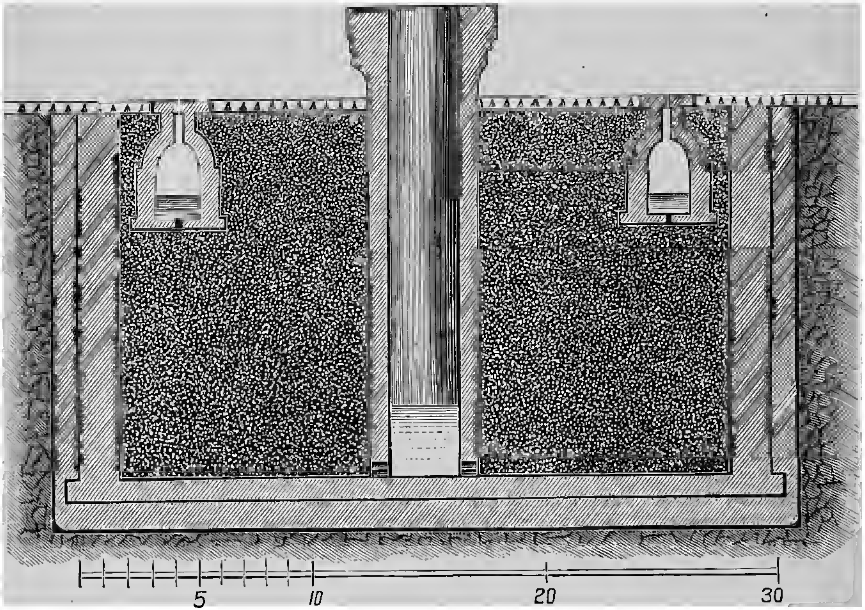

FIG. 1.—Section of rain-water cistern at Venice.

An excavation is made in the soil as deep as practicable, generally about ten feet, and a brick floor and walls are built with a backing of puddled clay, so as to be water-tight. The walls are sometimes vertical, as shown in the figure, and sometimes they slope outward. A well-hole is built of brick, water-tight except at the bottom, where openings are left. The cistern is then filled with sand, and drains are constructed as shown in the figure, to collect and distribute the rain-water which runs from the houses and falls upon the streets and courtyards. The water is thus subjected to filtration through sand, and, as there are no draught-animals in Venice, the street-wash is not as bad as it would be in other places. The sand, being fine, holds the water and delivers it gradually into the well-hole. Of course, the cistern must be made larger than would otherwise be necessary, because the sand itself must occupy nearly two-thirds of the total space, and thus leave only about one-third for the storage of water.[1]

It has already been said that the rain-water which is used for drinking should be filtered, but it will perhaps be better to discuss the subject of

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[1] Water for drinking has also been brought from the main-land in boats, and a few years ago a project was under discussion for introducing water by an aqueduct. The figure of the cistern, Fig. 1, is taken from Hagen's Wasserbaukunst.

household filtration, after we have considered other means of supply, for, however much we may deplore the fact, it is, and probably always will be true, that much of the water supplied by public works requires filtration in the household.

We have seen that, as far as the question of a general water-supply is concerned, it is not at present practicable to collect the rain as it falls, and, consequently, from a limited district, but that we must allow it to fall upon the ground, and then take water which is collected over what may be, comparatively, a very wide area. We pass now to our second division of available sources of water-supply, namely, surface-waters, including streams and rivers.

On Rivers as a Source of Supply.

Many rivers begin with the clear mountain streams of pure water flowing over a rocky bed, dwindling in the heat of summer, and increasing to torrents in the time of rain, or in the spring when the snows are melting. Others issue from a marsh, or from a forest, where the vegetable accumulations many feet in thickness hold the water like a sponge, and gradually allow it to drain away.[1]

As the river flows, it receives constant accessions to its volume, not only from tributary streams, but also from the ground-water, which, especially in gravelly or sandy regions, is continually passing into it. Occasionally a river, passing over the outcrop of upturned rocky strata, loses a portion of its water or disappears altogether; but, as a rule, it increases in size from its source to the sea, in spite of the evaporation which takes place from its surface.

The water, in its passage over or beneath the surface of the ground, dissolves both mineral and vegetable matters. Few rocks or mineral deposits are absolutely unaffected by water: on some, water—especially natural water charged with more or less carbonic acid—exerts a solvent action; others are decomposed, and yield new compounds to the water, so that the water of rivers and lakes varies very greatly, according to the situation or geological character of the location. It is further true that the water of the same stream is subject to considerable variation from time to time.

There are a number of objections to the use of river-water for domestic supply. One objection is the high temperature which the water acquires in summer. In this country we do not lay much stress upon this point, as the use of ice is so general, and it would, indeed, be quite impracticable in many cases to insist upon obtaining a water of anything like a uniform temperature the year round. Most streams are open to the objection that they are liable to become turbid at certain seasons, especially in times of freshet, and are also liable to become colored when the stream

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[1] See, for example, a recent article on the "Water-Supply of Rivers," by George Cahoon, in the Popular Science Monthly for July, 1878.

flows through a peaty region. The most important objection is their liability to pollution by becoming carriers of manufacturing refuse or of the sewage of towns: this objection we will proceed to discuss somewhat fully.

It is very obvious why a flowing stream should be considered the natural carrier of all waste matters which, in solution or in suspension, can be borne along by the current. Unfortunately, the condition of many streams in England, and that of a few in our own country, show that there are those, ignorant or reckless, who do not hesitate to throw all sorts of insoluble and heavy refuse into the beds of streams, regardless of the shoaling of the channel or such alteration of the bed and banks as leads to destructive inundations and other inconveniences.

In our own country we know comparatively little of the pollution of rivers. In England, however, owing to the density of the population and the variety and extent of the manufacturing establishments, many of the streams are in a fearful condition.

The following is a quotation from one of the English reports with reference to the rivers Aire and Calder:

"The rivers Aire and Calder and their tributaries are abused by passing into them hundreds of thousands of tons per annum of ashes, slag, and cinders, from steam-boilers, furnaces, iron-works, and domestic fires; by their being made the receptacle, to a vast extent, of broken pottery and worn-out utensils of metal, refuse brick from brick-yards and old buildings, earth, stone, and clay from quarries and excavations, road-scrapings, street-sweepings, etc.; by spent dye-woods and other solids used in the treatment of worsteds and woollens; by hundreds of carcasses of animals, as dogs, cats, pigs, etc., which are allowed to float on the surface of the streams or putrefy on their banks; and by the flowing in, to the amount of very many millions of gallons per day, of water poisoned, corrupted, and clogged by refuse from mines, chemical works, dyeing, scouring, and fulling worsted and woollen stuffs, skin-cleaning and tanning, slaughter-house garbage, and the sewage of towns and houses."[1]

We have very few rivers in the United States of which such a description could be given, although in some of the more thickly settled parts of the country, there are instances of streams which have become hopelessly foul.

Of course, the substances which, as refuse from manufacturing establishments, or from the household, find their way into running streams, are of very diverse sanitary importance; some of them are such as to be universally regarded as unfit to admit to any stream—those, for instance, containing lead, arsenic, etc.; but a large amount of refuse material is of such a character as to be, except in excessive quantities, of no appreciable influence on the human system. Many waste liquors, which appear to be very offensive, contain in reality very little of anything actually injuri-

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[1] Third Report of the Commissioners appointed to inquire into the best Means of preventing the Pollution of Rivers (Aire and Calder), 1867, Vol. I., p. 11.

ous—such, for example, are spent dye-liquors; they communicate a very foul appearance to the water for some distance, yet contain a comparatively small amount of solid matter, and, if discharged into a stream of considerable size, are soon disseminated through it, and diluted to a very great extent.

The compounds of soda, potash, lime, etc., which go to waste are, as a rule, harmless. In fact, it sometimes happens that, if the stream is already somewhat polluted, positive advantage may come from the refuse of some manufacturing operations. Thus, copperas (sulphate of iron) discharged into a stream polluted with sewage might actually improve the water, although it would not make it fit to drink. Much depends, of course, upon the size of the stream into which the refuse is thrown. Thus, it has been calculated that into the Merrimack river, at Lowell, Mass., even during the summer, it would be necessary to throw more than 100 tons of solid matter daily in order to increase the amount in the water by one grain to the gallon; but another and smaller stream might be hopelessly fouled by a single factory.

Different in character, however, from much of the refuse of manufacturing establishments is the sewage coming from dwellings, or the sewage (in its more restricted sense, of excremental matter from animal sources) which comes from factories. In fact, this foul material coming from establishments employing a large number of operatives, is likely, in many cases, to have a more injurious effect upon the stream into which it is thrown than the refuse from the manufacturing operations. There are, however, some branches of industry which discharge refuse material offensive and dangerous to health; such material is discharged from tanneries, wool-pulling and hide-dressing establishments, slaughter-houses, and rendering-houses. With the present feeling of the liability of injury from the presence of decomposing organic matter in drinking-water, and of the possibility of the propagation of specific diseases by excremental matter thus introduced into the system, too much stress cannot be laid upon the importance of preventing the discharge of such refuse and of sewage in its more restricted sense into any stream or pond used, or likely to be used, as a source of water-supply.

The difficulties at present in the way of the satisfactory purification or utilization of sewage and of many forms of manufacturing refuse, make it impossible absolutely to prevent the discharge of all such matter into running streams, and it seems inevitable that certain streams should be sacrificed and allowed to serve as carriers of waste. Of course there must be a limit even here, and the stream should not be allowed to approach the condition of the Aire and Calder, mentioned above, and thus become an actual nuisance.

The use of the same stream as a carrier of waste and as a source of supply is to be deprecated, and, on this account, it is manifestly unjust that one town should be allowed, at its own option, to discharge its sewage into a stream which, lower down in its course, would otherwise afford suitable drinking-water to other towns. If certain streams must be devoted to the baser use, this should be done by convention or by some central authority. Indeed, it would be of great advantage if the entire question of water-supply and disposal of sewage for a certain drainage area or water-shed were under direction of some central board or some one officer. The kingdom of Würtemberg, with its area of 7,500 square miles, took a step in this direction in the year 1869, when it created a new office, that of "Staats-Techniker für öffentliche Wasserwerke." It was made the duty of the Staats-Techniker to superintend the planning and construction of all public works for the utilization of the available river and spring waters, and to advise, in matters of water-supply, the local authorities of any village, town or city within the kingdom—this advice including the preparation of plans and estimates, and being without cost to the community asking the advice. We have already alluded (page 222) to the water-supply of the district of the "*rauhe Alb*," which was one of the results of the establishment of this office.

Self-purification of Water.

But it is said that, even admitting the liability, or even possibility, of injurious effects following the use of water polluted to a considerable degree—of water which gives evidence to the eye or to the taste of the presence of a marked amount of impurity—may not this water subsequently become suitable for use by the action of natural processes? It is indeed often stated that "if sewage matter be mixed with twenty times its bulk of ordinary river-water, and flow a dozen miles, there is not a particle of that sewage to be discovered by chemical means." This may be true. The statement rests, however, upon a fallacy and an assumption. The fallacy consists in supposing that a water to be unwholesome or dangerous must contain enough animal matter to be recognized readily by chemical tests—enough, in fact, to be expressed in figures; the assumption is that the injurious portion of the organic matter is that which undergoes rapid decay. This last assumption may be probable, but it is by no means proved.

The alleged self-purification of running streams may be investigated by laboratory experiment and by observation on actual rivers. By passing water in a small stream from vessel to vessel, the Rivers Commission in England have shown that, not only is a flow of twelve miles insufficient to destroy the organic matter of sewage when mixed with water in the above proportion of one to twenty, but also a flow of one hundred and sixty miles is far from sufficing for that purpose. We know very well that when an organic mixture like dilute sewage is exposed to the air, decomposition—chemical change—soon sets in, and many of the substances are altered in character. It would, however, probably take an almost infinite time in a dilute solution for the oxidation to proceed far enough for all the nitrogen and carbon, which are the characteristics of the organic matter, to escape as carbonic acid, free nitrogen or ammonia, or to remain as inorganic compounds, *i. e.*, as nitrates and carbonates. Some organic substances are readily decomposed in water. Thus, urea, a compound which occurs in urine, decomposes so rapidly into carbonate of ammonia, that it is rarely found in the most polluted waters. On the other hand, bits of muscular fibre, or of epithelium, will remain for months in water and still be readily recognized under the microscope. Even substances which decompose with rapidity when in a concentrated condition, are tolerably permanent when diluted. The Rivers Pollution Commission mixed some urine with water, in the proportion of one gallon of urine to 3,077 gallons (imperial) of water. The mixture was agitated from time to time and samples taken for analysis. The results, expressed in parts in 100,000, were as follows :

	Organic carbon.	Organic nitrogen.
Immediately after mixture, Feb. 17, 1874........	0.282	0.243
" 18, "	0.298	0 251
" 19, "	0.244	0.255
" 24, "	0.225	0.253
" 25, "	0.214	0.259
" 28, "	0.214	0.276

In spite of these experiments, however, it cannot be denied that some chemical change does take place in a polluted stream, and the question arises, whether the readily decomposed substances are the ones which cause the injurious effects ascribed to impure waters, or whether the products of their decomposition or the more permanent of the polluting substances may be equally injurious. Then, if the germ theory is correct, and if what we know of the permanence of other germs whose growth is traceable can serve for analogy, we should infer that these germs might well resist the action of the air or of the oxygen dissolved in the water.

If we leave the laboratory for the field, we shall find many streams where the impurity seems to decrease as the stream flows ; it is, however, difficult to find one which flows for a considerable distance without receiving tributaries. Of the two cases presented in the table on the following page, the Blackstone receives several unpolluted affluents, and the distance between the extreme points on the Merrimack is only 11 or 12 miles.

The Blackstone receives nearly all the sewage of Worcester, and a few miles below the city it is very foul ; but at Blackstone it has become quite different, and has even been proposed as a source of water-supply. Lowell and Lawrence are both large manufacturing towns, and all the liquid waste from the factories and from the cities themselves is discharged into the Merrimack. The question then arises: What has become of the sewage of Worcester, and why does not the Merrimack show more contamination from the cities and manufactories of Lawrence and Lowell?

The principal causes which contribute to the apparent disappearance of the refuse received by the river are three, and these, in what seems to be the inverse order of their importance, are oxidation, deposition, and dilution.

EXAMINATION OF FLOWING STREAMS.

(Results expressed in parts per 100,000.)

LOCALITY.	Ammonia.	"Albuminoid ammonia."	Solid residue.			Chlorine.
			Inorganic.	Organic and Volatile.	Total at 212° F.	
BLACKSTONE RIVER. (1873.)						
A few miles below Worcester	0.370	0.041	9.00	2.70	11.70	1.60
At Milbury, about 5 miles lower down on the river	0.025	0.022	3.30	3.20	6.50	0.68
At Blackstone, about 20 miles lower down stream	0.005	0.015	3.88	2.20	6.08	0.52
	0.004	0.016	2.76	2.32	5.08	0.40
MERRIMACK RIVER. (1873.)						
Mean of 11 examinations above Lowell	0.0047	0.0114	2.37	1.73	4.10	0.14
Mean of 12 examinations below Lowell and above Lawrence	0.0044	0.0110	2.41	1.69	4.10	0.20
Mean of 11 examinations below Lawrence.	0.0031	0.0127	2.64	1.79	4.43	0.18

Oxidation.—Although it is not practicable, in the case of a running stream like the Merrimack, to trace the progress of the destruction of the organic material by oxidation, yet there is no doubt that an appreciable amount is so destroyed. Moreover, a considerable amount of the organic matter is consumed by fishes and by the microscopic animals which inhabit the water, or is converted into simpler compounds through the agency of plants of higher or lower order.

Deposition.—Much waste material thrown into rivers is made up wholly or in part of substances insoluble in water. A portion, and a very considerable portion, even in a running stream, is deposited upon the bottom or stranded upon the banks. This deposition can often be very plainly observed in the immediate neighborhood of the points of discharge. Other chemical changes, besides that of oxidation alluded to above, take place, especially where the refuse is that from manufactories. Waste liquors from different manufacturing operations meet and cause the formation of new and, in many cases, insoluble compounds. Suppose, for instance, that we have a wire-working establishment or any other iron-works, where, for any purpose, the iron is cleaned by sulphuric acid, and, as is often the case, the copperas, or sulphate of iron, is allowed wholly or in part to go to waste. Suppose there is a tannery below, the spent liquors from which run into the same stream. The result may be that the stream is converted into ink by the chemical action which takes place between the two waste liquors; the ink may be very dilute, to be sure, but the water might be too black to drink or to use for any domestic purpose. If the stream is discolored by this alone, it may become perfectly clear again after a flow of a dozen miles, or even less. In such a case, no doubt, the chief cause of the clearing of the water is the deposition of the colored particles which make up the ink. Every one knows that some varieties of ink become blacker on exposure to air. The ink formed by mixing copperas and tannery waste would change by the action of the oxygen of the air, but there would be no considerable destruction of organic matter; the improvement in appearance would be due to subsidence.

There are a great many substances which, when treated with water, form a sort of imperfect solution; the resulting mixture appears to be transparent, as though the solution were perfect, but the substances themselves are readily removed from the solution by forces which seem to be mechanical, especially by adhesion to other substances where no chemical action can be distinguished. This is especially true of organic substances, and it is well known that almost any finely divided solid matter, as it deposits in a solution of organic coloring matter, will drag down more or less of the coloring matter with it. Such a deposition is continually going on in rivers and ponds.

Dilution.—By far the most important reason of the apparent disappearance of sewage and other waste material, is the fact that the amount of solid matter is so small, compared with the volume of water into which it is thrown, that it is disseminated through the mass, and thus lost to observation, and, in many cases, to chemical tests. If we refer to the table on page 232, and compare the results obtained in the examination of the Merrimack river above and below Lawrence, we shall not find any such increase in the amount of organic matter as we should anticipate from a knowledge of the fact that between these two points the river receives the refuse from nearly all the manufacturing establishments, a large proportion of the excreta of the factory operatives, and a portion of the sewage of Lawrence. Moreover, when the examinations were made, the lower station was so short a distance below the city, that no chemist, probably, would believe that any considerable destruction of organic matter could take place in the rapid flow for so short a distance; and if, from chemical grounds, the evidence was not sufficient, the floating soap-suds, with still unbroken bubbles, and other materials borne down upon the current, showed the same thing. Here, at any rate, dilution must be supposed to play a very important part, as may be also shown by considering the relative amounts at the two points of some inorganic constituent which could not decrease in amount, except as a result of dilution. Such a constituent we have in chlorine, compounds of which (especially chloride of sodium—common salt) occur in all sewage and in most forms of manufacturing refuse. All the chlorine used in the process of bleaching is eventually washed away, and that contained in the various compounds of this element which are used in dye-houses and print-works, finds its way in the end into the drains of the establishments.

Now, although large quantities of chlorine compounds are thrown into the river at Lawrence, yet there is no apparent increase of the proportion of chlorine in the water below the city. In this case we have a substance readily traced. The chlorine cannot escape from the river in gaseous form, nor does it deposit in insoluble combination, and yet the first inspection of the analytical results would lead, perhaps, to the conclusion that there was no real increase of impurity. From these considerations it is evident that in the case of the soluble *organic matter* it is not necessary to suppose any destruction or decomposition; the apparent decrease or lack of increase may be explained, as in the case of chlorine, by the fact of dilution; and where the distance between the two points of examination is so short, as in the instance now under discussion (above and below Lawrence), this is no doubt the main cause concerned.

From a calculation made in 1873,[1] it appears that, even in summer, when the river is at its lowest, as much as 100 tons of *dry* material would have to be thrown daily into the river, in order to increase the solid matter in solution to the extent of one grain to the gallon. From this we can see how large an amount of refuse matter could be thrown in without producing a noticeable effect, for the volume of water is continually increasing as the stream flows on; moreover, this 100 tons of *dry* refuse stands for an enormous amount of such material as is actually discharged. The waste liquors from many manufacturing operations are very dilute, and although sometimes the stream into which the refuse is poured is colored for a considerable distance, yet the actual amount of solid coloring matter may not be very large. With reference to sewage matter proper, it may be said that urine contains only about 4 per cent. of solid matter, fæces only about 27 to 30 per cent., and the mean amount of dissolved solids in Boston day-sewage was, in 1872, only six one-hundredths of one per cent. (0.06 per cent.).

It would appear from what precedes, that there is liability of overrating the amount of spontaneous purification to which a running stream is subject, and it is certain that we cannot decide with confidence as to when a stream, once polluted, becomes fit to drink; moreover, as it is not possible by any practicable chemical treatment or by any process of filtration to make a polluted water wholesome, it is safer not to use as a source of domestic supply a water which is known to have been seriously polluted.

On Ponds and Lakes as a Source of Supply.

In the general character of the water, ponds and lakes do not differ essentially from rivers, and on some accounts they are to be preferred to rivers as sources of supply, especially because they are less likely to be turbid from time to time, and are also less liable to become polluted. The running streams furnish advantages in the way of water-power, and afford a ready means of disposing quickly of waste substances, so that their banks are more likely than the shores of a pond to become the seat of manufacturing industries.

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[1] See Report of Mass. State Board of Health, 1874, p. 80.

In preferring lakes or great ponds to rivers as sources of supply, it must be borne in mind that the objection is not to the river as such. A river may, considered by itself, afford a most excellent, a perfectly unobjectionable, supply of water. Its sources may be clear and pure mountain-streams; it may flow over a rocky or gravelly bed, uncontaminated by refuse from the habitations and factories of men, and free, or nearly so, from vegetable matter; it may be so situated that no liquid refuse finds its way to it, without being first purified by filtration through a sufficient amount of natural soil. In this case no objection can be made to using the water for all domestic purposes. On the other hand, a pond or lake may be, in itself, a very objectionable source of supply, especially if so situated as to receive direct drainage, or if fed by streams which are used as sewers. It is an indispensable condition in the choice of any stream or lake as a source of water-supply, that the source should not only be free from actual present contamination, but should also be so situated as to render it possible to protect it from contamination in the future.

There is one trouble to which the water of ponds is much more liable than that of rivers, namely, to growths of minute vegetable organisms. This is a matter which concerns especially the water-supply of the Eastern and Middle States, where the preference is for a very soft water, and where surface-water from natural or artificial ponds is largely employed. No natural water which is exposed to the air and light, whether in pond or river, is ever entirely free from vegetable and animal life, but the lower orders, both of animals and plants, flourish most abundantly in still water. If the water is at the same time shallow, so as to be readily warmed by the rays of the sun, the growth may be very luxuriant.

We are not now concerned with the plants of higher order, many of which live in the water. The plants which are known as eel-grass, pond-weed, pickerel-weed, etc., which have roots and leaves, and also at the proper season flowers, are in themselves, while growing, of no disadvantage to the pond or reservoir in which they grow.

There are also many harmless plants which rank much lower in the scale. Such are the so-called "confervoid" growths, caused by plants of filamentous structure, grass-green, or in some cases bluish-green in color, forming tangled masses readily removed from the water, and, when so removed, shrinking enormously in apparent bulk, and drying away to a grayish or colorless mass, in some cases looking almost like coarse paper. These belong to the class of cryptogamous (non-flowering) plants which the botanists call *algæ*—plants which grow in the water, or in moist places, and usually contain chlorophyll (green coloring matter) or some allied substance. Plants of this character grow in almost all reservoirs, or other bodies of water exposed to the light and air, both in still and running water; they either float about in masses, or are attached more or less firmly to rocks and stones and other solid objects. By their growth they do no harm to the water in which they flourish; and as they are readily arrested by ordinary wire screens, or easily removed by rakes or scoop-nets, their presence causes no serious inconvenience in water used for town-supply.

Fig. 2 shows several sorts of these algæ as they appear when magnified: *a* is a *spirogyra;* *b* a *zygnema;* and *c* an *œdogonium;* the first two being shown in the process of conjugation. The different species occur of a variety of sizes. These particular specimens are magnified between 80 and 100 diameters.

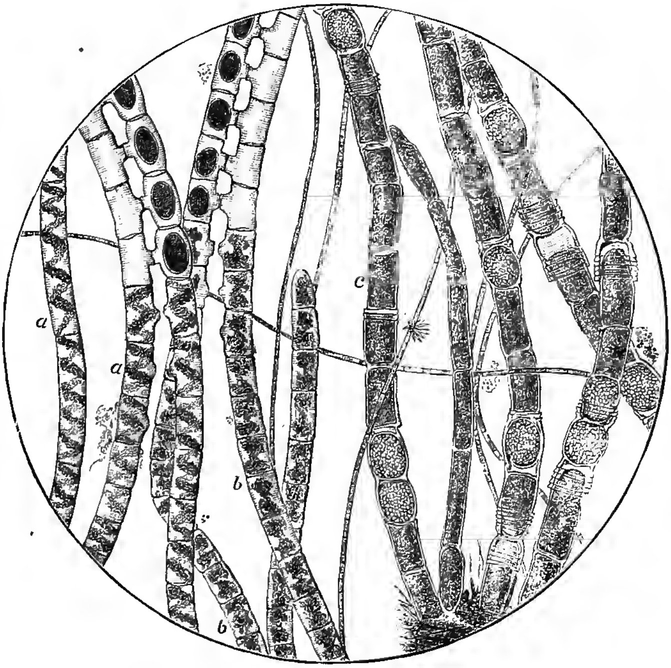

FIG. 2.

The vegetable organisms which cause the most trouble and inconvenience are those which appear as greenish specks, or minute straight or curved threads, diffused through the water—visible enough if a large quantity of water be looked at, but perhaps almost escaping notice in the small quantity which would be taken up in a single glass. It is true that the individual plants are in some cases distinguishable by the naked eye; but their form and structure can be made out only by use of the microscope. If collected together as a scum, which often happens, especially on the windward shore of a pond, the scum is not coherent, is easily broken up, either by a wind setting in the opposite direction, by a shower of rain, or by artificial agitation. The appearance has been sometimes described as that of meal or of fine dust scattered through the water. The number of individuals is almost infinite; and under favorable conditions they increase with great rapidity. Their presence gives a decidedly green or greenish yellow tinge to large bodies of water; and their death and decay often cause considerable offence to the sense of smell of those sojourning in the neighborhood, and to the sense of taste of those obliged to drink the water.

While very many species of the minute *algæ* present this general appearance, the number of species which are known to increase to such a great extent as to completely fill the waters of ponds of many acres area, and to cause sensible inconvenience, is comparatively small—the most common in New England seeming to be the *Clathrocystis æruginosa;* but certain plants referable to the *Nostochineæ* are not uncommon alone, or in company with the *Clathrocystis.*

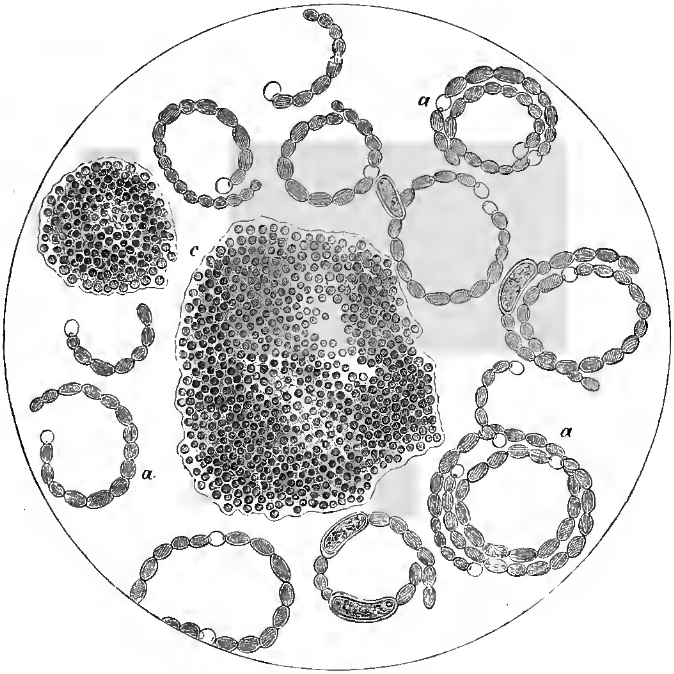

FIG. 3.

Fig. 3, *c* gives a general idea of the appearance of the *Clathrocystis æruginosa* when magnified some 300 diameters. This plant is often found in much larger masses than indicated in the cut; in fact, the little sack-like masses are sometimes large enough to be made out by the unaided eye, although no idea of the structure can be thus obtained. Fig. 3, *a* attempts to give an idea of the *Anabæna circinalis*, one of the *Nostochineæ;* this plant occurs very frequently in ponds and in sluggish streams. Another common variety of the same genus is similar, except that the filaments are straight, instead of curved; and there are other genera of *algæ* which occur in the same way as the *Anabæna,* and present a similar appearance.

There is no reason to believe that the presence of these minute *algæ* gives an unwholesome[1] character to the water; and the inconvenience caused by their presence and decay is fortunately of short duration, being, as a rule, for only a few weeks of the year. They are not a sign of impurity, as they grow in ponds which are far removed from all sources of contamination; still a pond known to be subject to such growths would be, on this account, less desirable as a source of supply. There is no means known of preventing the growth, but by a properly-conducted filtration the water may be made much more acceptable to the eye and to the taste.

Impounding reservoirs.—Many towns in this country, some in England, and a very few on the continent, supply themselves with water from artificial ponds made generally by damming a brook or small stream which flows through a valley, across which a dam can be conveniently and safely built. Streams which seem to the uneducated eye altogether inadequate are thus made to furnish a uniform and considerable supply. The disadvantage of this method is that the reservoirs are very often made by flooding land which is under cultivation, or, at any rate, covered with more or less vegetable growth. The land-plants being killed by submersion, undergo decay and communicate to the water for some time an unpleasant appearance and a disagreeable taste. Again, in such new-made reservoirs, it is apt to happen that there is a considerable portion about the edges of the pond where the water is very shallow, and where, consequently, there is opportunity for the growth and subsequent decay of aquatic plants. It would be a great advantage if in these reservoirs there were never less than twelve or fifteen feet of water, although even if this were, in all cases, practicable, it would not prevent the growth of minute algæ such as have been described as of frequent occurrence in natural ponds. These artificial ponds, as time passes, become more and more like natural ponds fed by surface-waters, and are open to the same general objectious and require the same care to protect them from polluting influences.

On the Ground-Water as a Source of Supply.

Whenever the rain falls upon a deposit of sand or gravel, or other material which affords little resistance to the passage of water, it quickly disappears from view, and if there be an underlying impervious stratum, such as of clay, the water accumulates above it to form what is called the *ground-water* of the locality. The distance from the surface of the ground to the surface of the water in any particular place is dependent in

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[1] There is one case on record where cattle have been killed by drinking pond-water which contained large quantities of a species of *Nodularia,* a plaut which has something of a resemblance to the *Anabæna.* (See Nature, XVIII., 1878, p. 11.) This was in Australia. No such cases have come to the knowledge of the writer here. When the *algæ* are alive and fresh, horses and cattle drink the water readily, in preference to spring-water: when decay takes place, the water sometimes becomes so offensive that they refuse to drink it. In this condition it is manifestly unsuited for domestic use.

a measure upon the amount of water which falls as rain or snow, and is consequently subject to considerable variations; but while the height of the ground-water is subject to variation, a very uniform relative level is often maintained over wide areas. The height of the ground-water and its fluctuations are important factors in the sanitary condition of any locality.

For limited distances the water-surface may be nearly horizontal, and sometimes this deposit of water can be regarded as an underground lake or pond filling a basin of impervious materials. More often, however, there is not only an inclination in the surface of the ground-water, but also a movement, a sluggish flow, toward a lower point where water appears to the eye in pond or river. Most rivers of any size flow for a portion of their course through beds of sand and gravel which have been deposited by the river itself at an earlier stage of its history, and many ponds and lakes are situated in similar deposits. In any such case, near the banks the water stands at approximately the same level in the gravel and in the river or pond; and, as we recede from the banks, the water-level is found to rise more or less regularly according to the character of the deposit. The ground-water contributes in no inconsiderable amount to the volume of the pond or river, issuing as a rule unobserved, but sometimes in springs or streamlets. It is, however, important to notice that a river does not generally cut entirely through the water-bearing stratum, and often there is beneath its bed a deposit of water differing in character from that of the stream itself. In fact, it is well known that the beds of some modern rivers are many feet above their ancient beds, and the intervening deposits are filled with water moving slowly toward the mouth of the visible stream. Again, in regions where the rivers disappear during the dry season, it is often possible to obtain water by digging into the river-bed when there is no longer surface-water to draw upon.

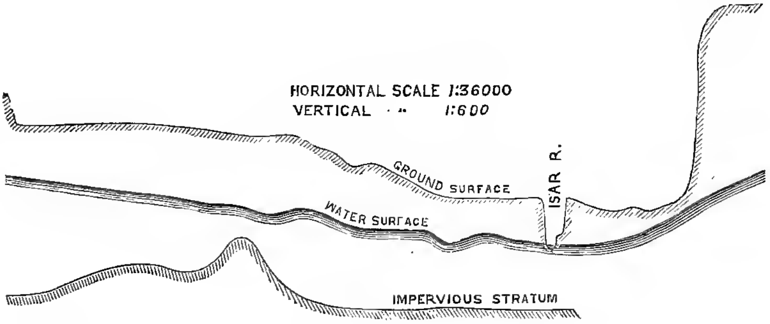

FIG. 4.

Fig. 4 will illustrate some of the relations of the visible river to the ground-water.[1] Of course, in this diagram the vertical scale is much ex-

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[1] From the I. Bericht der vom Stadtmagistrate München niedergesetzte Commission für Wasserversorgung, Canalisation und Abfuhr in den Jahren 1874–75; Munich, 1875. The profiles in Figs. 4 and 5 are selected from a great number which appear in the reports of this commission.

aggerated, but it shows plainly that the depth of water in the river is very small compared with that of the entire ground-water.

The inclination of the ground-water depends mainly upon the character of the water-bearing stratum itself and the readiness with which it allows water to pass through it. When the water-bearing stratum is thin the configuration of the underlying impervious stratum also exerts an influence in the matter, especially in determining the direction of the flow; but that very considerable irregularities may exist in the surface of the impervious stratum itself without altering the general inclination of the ground-water, is evident from Fig 5. The configuration of the surface of the ground has little influence in the matter, and it is seldom possible, from surface observations, to argue as to the conditions obtaining below the soil except in a general way.

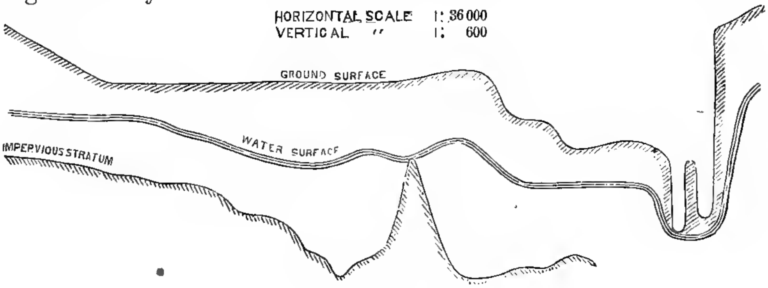

FIG. 5.

On the Ground-Water as a Source of Household Supply.

The ground-water has been made use of as a source of water-supply from time immemorial. When obtained by sinking a well into a stratum of sand or gravel which has not been artificially disturbed, it is, as a rule, bright and clear, and free, or nearly free, from organic matter. Although originally coming from the atmosphere, in its slow passage into and through the ground the water has been subjected to a long process of sedimentation and filtration, combined with processes of oxidation. In this sense the water may be said to have been purified by *natural* filtration; the process, however, is not brought about by the means taken to collect and utilize the water, but has been practically completed before the demand is made upon it.

The objection to such shallow wells as a source of drinking-water is mainly on account of their liability to contamination. This liability will be best understood by a consideration of what happens when water is drawn from such a well.

Of course, the pumping of water from the well causes the lowering of the natural water-level; and if the pumping be regulated so as to keep the level of the water in the well at a certain fixed point, as at *a*, Fig. 6, the ground-water in the neighborhood of the well also assumes a constant level, as indicated in the figure by the curved line *a b*. The influence of the pumping will be felt in all directions, as indicated by the plan, Fig. 7.

If the demand made upon the well be increased—that is, if the level of the water in the well is kept constantly at a lower point—the circle of influence is extended. The distance to which the *measurable* influence of the pumping is felt, in any case, depends, other things being equal, upon the character of the water-bearing deposit.

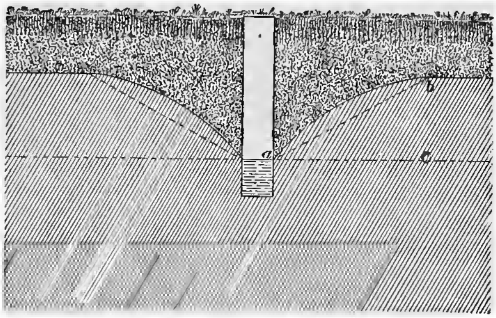

Fig. 6.

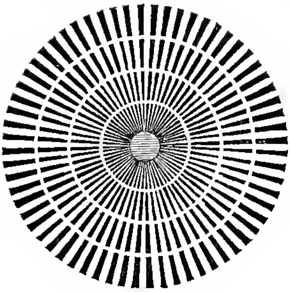

Fig. 7.

The taking of water from this underground supply resembles in many respects the taking of water from a pond or lake. Suppose that we have a lake or pond, as there are many, generally situated in valleys, with no considerable visible inlet, and yet from which experience has shown that a certain number of gallons daily can be withdrawn without affecting its level: if this lake be now filled with sand and gravel, we can still pump the same daily *quantum* (even more, owing to lessened evaporation); but, owing to the resistance of the material, the level of the water does not equalize itself at once, although, if the pumping cease, the water in the well soon rises to the normal level of the ground-water.

In order that the well should give a uniform supply, the amount of rainfall received over the region drained, and over the region which contributes to the underground supply, should be uniform. The level of the ground-water is subject naturally to some variations, according as the season is wet or dry. If there were no rainfall, or if the amount supplied by the rainfall were less than the amount pumped, the ground-water would be lowered eventually throughout the entire water-bearing stratum, practically to very nearly the level of the water in the well; or, to refer to Fig. 6, the point *b* would recede farther and farther, until for some distance the curve *a b*, the straight line *a b*, and the straight line *a c* would all three practically coincide; that is to say, if the lake which we took for comparison were no lake, but a cistern, it would be eventually pumped dry, or to the level of the suction-main.

It is quite evident that, in the case of shallow wells such as are now under consideration, if a cesspool or privy-vault be situated within the circle of influence of the well, any liquid which soaks from it into the ground will be likely to find its way into the well, unless the amount of liquid be too small to saturate the soil into which it soaks. In this case, the water is held by capillarity, and slowly evaporated, leaving in the soil a continually increasing amount of objectionable organic matter, which is liable, on the occurrence of heavy rains, to be washed into the well. This explains what has actually been found to be the fact, namely, that some wells are noticeably bad after heavy rains, while at other times the water seems to be good. On the other hand, where there is a more direct passage of offensive matter into the well, a heavy rain may dilute the water so that it will be better than in a dry time. In wells, as in almost everything else, difference of condition gives difference in the result.

In the case of a well supplying one or two families only, the circle of measurable influence, as far as the height of the ground-water is concerned, is quite small; but this is by no means the circle of possible contamination, for the water drawn from the well is not taken from that which falls within this limited area, but is taken from that portion of the ground-water which happens at the time to be passing through the well, so to speak. In most cases, as has already been stated, there is a movement of the ground-water, and it sometimes happens that a source of contamination may be very near the well without affecting it, owing to the fact that the direction of this movement is such as to carry the drainage away from the well. If the supply of water be abundant, it may be possible for offensive or injurious matter to be so diluted that no perceptible effect is produced on the well; but, as the ground becomes more and more charged with decaying substances, the danger of future contamination becomes greater.

Most wells are dug simply with the view of obtaining water and of having it as convenient to hand as possible; the cesspools are dug similarly, with a view to convenience, except that the demand here is that the liquid contents shall readily drain away. Provided the well furnishes an abundance of water, and the cesspool allows the liquid refuse to soak away, and, on this account, seldom requires cleaning out, there is little concern as to what goes on unobserved beneath the surface of the ground. In the course of time the well-water is discovered to be impure, either by a bad taste, or by analysis which has been grudgingly ordered owing to the suspicious sickness of some who have drunk the water.

There are other shallow wells which do not draw their supply from the ground-water, properly speaking, but are sunk so as to intercept the water flowing through a rocky fissure, or are sunk into the rock so as to form a collecting basin or reservoir. Such wells are in some respects even more liable to contamination than the wells sunk into the ground-water, for, in the pores or interstices of a gravelly soil, there is a continually changing body of air which affords more or less opportunity for the oxidation of the organic matters, so that the process of rendering the well unfit for use is a gradual one; and often a well will furnish good water for a long time and then become suddenly bad—suddenly, it seems to those who have not been aware of the progress of the pollution. On the other hand, a well which is sunk into the rock may receive from a considerable distance sewage-matter which has found its way almost directly into the well along the surface of the rock, or through some fissure.

A great many instances might be brought forward where cases of sickness have been supposed with good reason to be due to drinking polluted well-water. Figs. 8 and 9 represent the situation of two wells in Lynn, Mass. The figures are taken from a paper by Dr. Pinkham, in the Eighth Annual Report of the Massachusetts State Board of Health.

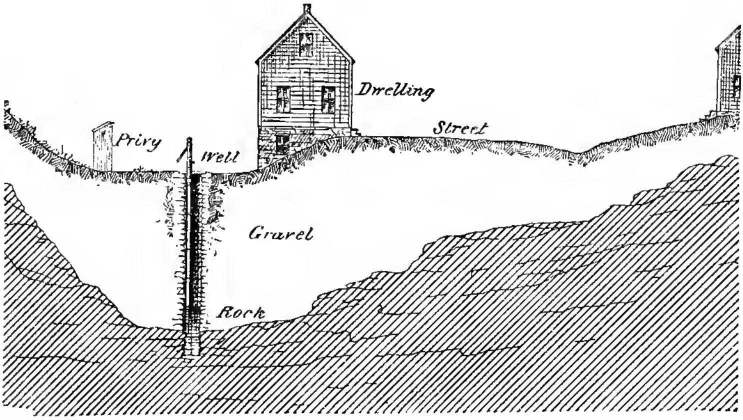

FIG. 8.

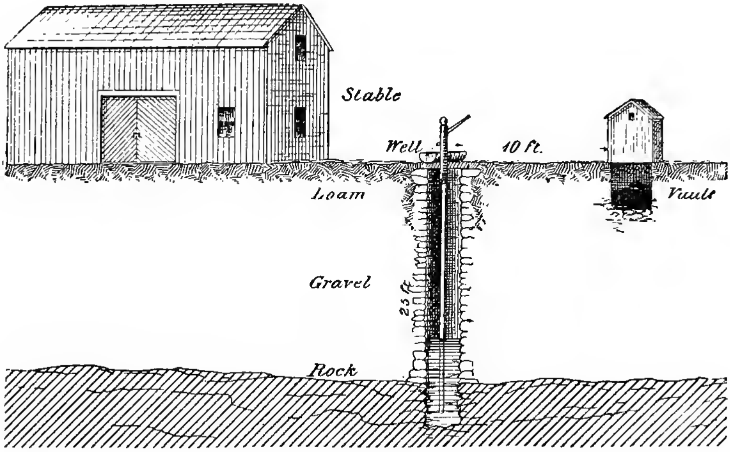

FIG. 9.

"Five cases of typhoid fever occurred in 1875 in the house shown in Fig. 8, and seven more, with one death, among other persons using the water. The house became the centre of infection for the whole neighborhood."

Analysis proved the water to be highly polluted, and the figure shows how favorably the well is situated for receiving both surface-drainage and soakage from the privy. In 1876 five cases of typhoid fever occurred in the house which drew its water from the well shown in Fig. 9, and led to the examination of the water, which proved to be badly contaminated. These two cases are but illustrations of what exists in hundreds of other localities. In digging shallow wells the site should be chosen so as to avoid, as far as possible, all contamination; the top of the well should be protected by a cover, and the upper portion of the well-hole should be thoroughly cemented in order to prevent the direct entrance of surface-drainage.

It ought also to be said, in this connection, that there are some close, especially clayey soils, which do not allow free passage of water, and the line where the soil seems saturated is not the level of a true ground-water. In such locations the opening of the well serves in a measure to drain the soil and lower the level of saturation, even when little water is pumped. If the water-bearing deposit, however, is open, and allows free passage of the water, the mere opening of the well has no effect. These "drainage-wells" are liable to contamination, like other shallow wells, and the water is naturally inferior to that obtained from a freely moving ground-water.

On the Ground-Water as a Source of Town-Supply.

When a village or town is so located that an abundant supply of water can be secured from the ground-water without going to a distance, it is much better to supply the whole community from one or several large wells than it is for each family to have its individual well. This, of course, involves some expense, but gives greater security from contamination; for, while the individual wells are very liable to become polluted, the site of the larger wells can be so chosen as to make the risk from this source very small. It is generally desirable, and in some cases it is necessary, to determine by experimental investigation the direction of the flow of the ground-water. A large well drawing its supply from the ground-water is located in Prospect Park, Brooklyn, N. Y. It is about 35 feet in diameter, and supplies 250,000 gallons daily. The water is not used for domestic supply; but there are other localities in the country where such wells are in use. The supply of water procured in this way may often be very much increased by sinking a series of wells at short distances apart, or by having a single well, and running from it galleries into the water-bearing deposit. A comparison of Figs. 7 and 10 will show the effect of such a series of wells, or of a collecting gallery where there is a free flow of water.

The most favorable situation for a gathering well or gallery is in the neighborhood of a river (or lake), for two reasons: first, because at such a place there is almost certain to be a decided movement of the ground-water toward the stream; and, in the second place, the water from the

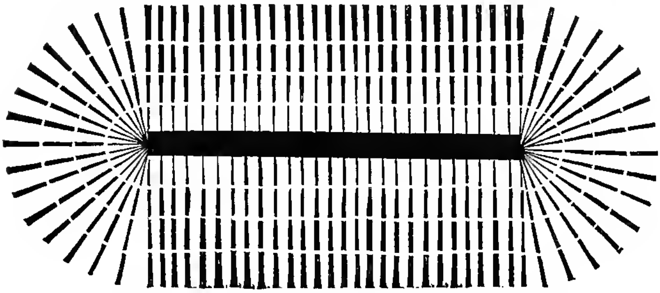

FIG. 10.

river can make up any deficiency caused by removal of the ground-water, by filtering through the bank and bed of the river.

For these reasons, the locality most commonly chosen is on the bank of a running stream in a deposit of gravel. The simplest form of collecting-works is the open basin; but in an open basin the water is exposed to the direct rays of the sun, and, in summer, becomes heated above its natural temperature; this favors vegetable growth, and in some places inconvenience has arisen from this cause. It is unquestionably better, and in warm climates it is essential, to have the basins covered.

Another method of utilizing the ground-water is to construct a covered gallery which shall permit the percolation of water into it, and from which the water can flow to the pump-well; for, as is indeed ordinarily the case, when the supply is taken from rivers, pumping-works are almost always a necessary part of such a scheme. There are many examples of collecting-galleries in Europe and in this country. A single example will suffice for illustration. The accompanying cut, taken by permission from Fan-

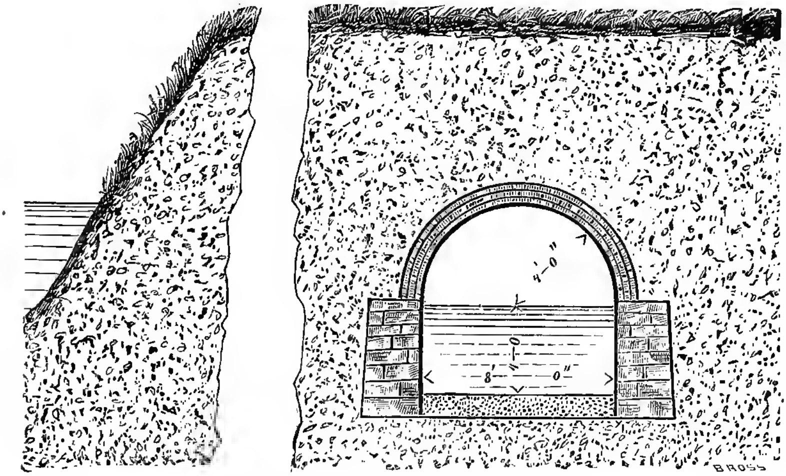

FIG. 11.—Filter-gallery, Lowell, Mass.

ning's "Water-Supply Engineering," represents the gallery at Lowell, Mass. This is on the northerly shore of the Merrimack river, and parallel with it, about 100 feet from the water's edge. Its length is 1,300 feet, width 8 feet, and height (inside) 8 feet. The side-walls and the semicircular brick arch are intended to be water-tight; and the water enters at the bottom, which is covered with coarsely-screened gravel.[1]

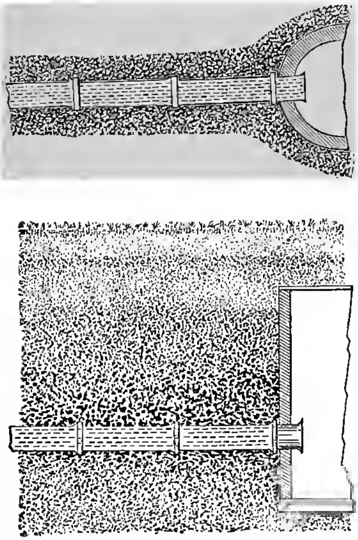

FIG. 12.

Another method of collecting the ground-water consists in employing, instead of such a gallery as has been described, a line of iron pipes, *i. e.*, practically water-mains, cast with a great number of narrow longitudinal slits, and laid with loose joints. These pipes collect the water, and conduct it to receiving-wells, from which the supply is pumped. In filling the trench in which the pipes are laid, the pipes are surrounded on all sides with coarse material of too large a size to fall into or through the slits, and the trench is then filled with screened material of decreasing size. The figure (Fig. 12) will give some idea of this method. A less elaborate mode of applying the same principle consists in substituting for the iron pipes ordinary cement or other unglazed drain-pipes, laid loosely. At Arlington, Mass., such an arrangement is in operation, the pipes being laid in the gravelly bed of an artificial reservoir, made by damming a small brook.

Sometimes the collecting galleries or pipes are, as in the instance just mentioned, placed actually beneath the bed of a river or pond. The figure (Fig. 13), represents the section of a collecting gallery (or filter gallery, as it is called), which is in actual use at a paper-mill on the Westfield river, in Massachusetts. The description of the gallery is as follows:

"The water is obtained from a gravel or sand bed which lies within the bed of the river when the water is high, although not covered with water for the greater part of the year. In this gravel-bed a trench of 250 feet long was dug of such depth as to bring the bottom of it as low as, or lower than, the bottom of the river at its deepest part, and of 6 feet or more in width. The trench was then filled to the depth of a foot with stones of various sizes, from small cobble to coarsest gravel stones, making the surface as even as possible, though with a slight grade downstream.

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[1] For a fuller description, see the Third Annual Report of the Water Commissioners of the City of Lowell, January, 1873.

"On this foundation a line of timbers 6 by 6 inches is laid on each side of the trench, 4 feet apart. Across these are placed and firmly nailed on, 3 feet apart, square frames 4 feet wide by 3 feet high, made of timber 6 by 6 inches, each frame strengthened in the centre by a standard 2½ by 6 inches from the top to the bottom. The top and two sides of this row of frames are covered with hemlock plank 2½ inches thick, and thus a filtering-gallery 250 feet long, 3 feet high, and 4 feet wide, is made.

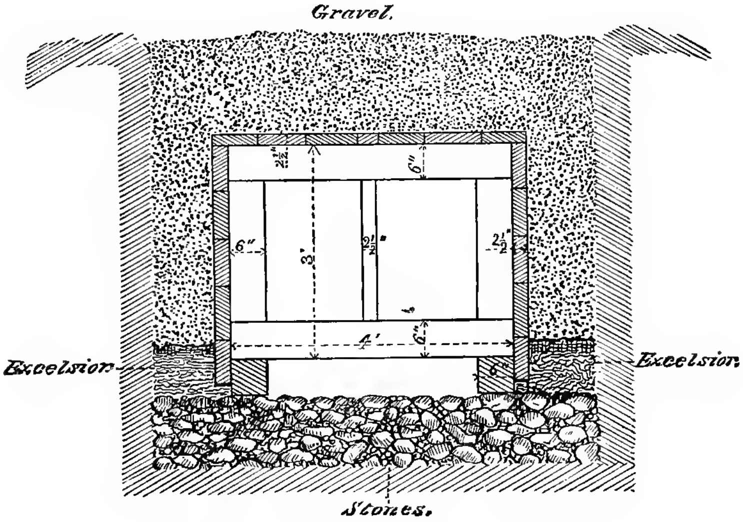

Fig. 13.

On the outside of this gallery, at the bottom, a filling of 8 inches of excelsior is lightly tramped down, and then the trench is filled up with the gravel, and the filter is complete. From this filter 600 gallons per minute of the clearest water are obtained. The filtration is upward and through the stone bottom: the gallery is kept full in low water by taking water through canals over the filter from a point in the river above."[1]

The account of this gallery has been given with some detail, to show that at a comparatively small expense it might often be possible for a village or small town to procure a supply of water of superior quality. The use of the so-called "excelsior," *i. e.*, practically fine wood-shavings, is not to be recommended, nor would it be necessary if the materials used in filling the trench were properly screened and graded—the coarsest being put first and the finest on top of all. Of course it would be necessary, in any particular case, to ascertain by experiment whether there was a suitable place for the location of such a gallery.

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[1] Ninth Annual Report of the Massachusetts State Board of Health, p. 180.

On the Source of the Water obtained by "Natural Filtration."

The water obtained by any of the methods which have just been described is to be considered as "ground-water." Even when the locality chosen is near to a stream, or, in fact, in the very bed of the stream, the water is taken in considerable measure from the underground supply, from the ground-water rather than from the river itself. In most cases, no doubt, some water passes from the river into the adjacent deposits, and contributes to the supply, but generally the larger proportion is not obtained from the river. This method of water-supply is often spoken of as the method of "natural filtration," and the water has been supposed by some to be derived from the stream (or lake) by simple filtration through the intervening bank. This view is incorrect, and the experience gained from artificial filtration would show that such a filtering bank, if it really did the work which it is supposed by some to do, would soon become clogged up and allow only a trifling amount of water to pass through, except where a tolerably rapid current prevented the lodging of sediment. In fact, in a number of places attempts have been made to procure a supply of water by natural filtration through the banks of a stream, and the attempts have failed in all cases where there has been no sufficient ground-water supply.

In explaining the source of a water which is obtained from a collecting-gallery, such as has been described on previous pages, it evidently is not necessary in all cases to call upon the neighboring river or pond, because, as we have already seen, there are some gathering-wells which are near no body of water, and which still furnish an abundant supply. The well in Prospect Park, Brooklyn, N. Y., is nearly two miles from tide-water, and the level of water in the well is considerably above tide. Here the 250,000 gallons which are daily pumped are evidently not filtered sea-water, but fresh water which would otherwise find its way into the sea or into strata underlying the salt-water.

Now, wherever a tolerably pervious and homogeneous deposit exists in the neighborhood of any river or pond, it is quite certain that there will be a ground-water which is moving more or less slowly and regularly toward the visible body of water. If a well be opened into this deposit, it will be possible to intercept and remove a certain quantity of water daily without drawing any water from the river[1] into the ground. The taking of the water would affect the level of the ground-water to a greater or less distance, as already shown by Figs. 6, 7, and 10, the distance depending upon the nature of the water-bearing stratum, and the abundance, or rather the natural rate of motion, of the ground-water.

Figs. 7 and 10 are taken from Salbach's Reports of the Dresden Water-

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[1] Hereafter, in speaking of "collecting-wells near the banks of a stream or river," it will be understood that the term "well" shall include also open or covered galleries or basins, and that the term "stream" or "river" shall also include "ponds" or "lakes." The essential points are the same in all of these cases.

Works. The experiments on which they are based were carefully conducted in the alluvial deposit on the banks of the Elbe, from which the water has been taken for the supply of the city. It was found that when the water in an experimental well was, by pumping, kept constantly 2.5 metres below its normal level, the height of the ground-water was affected in every direction for a distance of 60 metres (about 200 feet), and that the curve which the level of the ground-water assumed was the same as represented in Fig. 6. (If the figure is to apply to this particular case, the vertical scale is to the horizontal as ten to one, and the diameter of the circle is 120 metres.) Beyond this point the effect was inappreciable. In this case the gravel was extremely porous and the well was very near the bank of the river. The amount of water necessarily pumped, in order to keep the level at the point indicated, was 1.56 cubic metres per minute (about 600,000 United States gallons per day). More recent experiments have confirmed the earlier views as to the source of the main portion of the water.[1]

In applying the principles of Figs. 6 and 7 to the case of a well situated near a stream, if the river-bank were perfectly water-tight, the "circle of influence" would become a semicircle, or at least, a segment of less than a whole circle; otherwise things would be as before.[2] The bank is not, however, as a rule, even practically water-tight; but in the natural condition there is, as we have seen, a continual passage of the ground-water into the stream, except in case of sudden flood. No doubt, however, other things being equal, the passage of water from the ground into the river is much more easy than its passage from the river into the ground; for the particles of silt deposited on the bed of the river choke the passages between the grains of sand and gravel, and become, as it were, wedged in. Pressure from the outside tends to make the mass more compact and less pervious; but, if pressure be applied from the inside, the particles of silt are forced out or lifted as valves from their seats.

The main reasons for believing that the water obtained by the method of "natural filtration" is better designated as "ground-water" are three in number. In the first place, the general facts with reference to the ground-water which have just been stated, as well as those mentioned on page 239, lead to this conclusion; in the second place, the temperature of the water in the well or gallery differs from that in the river, being higher in winter and lower in summer, and varying within narrow limits unless the water is received in an open basin and exposed in a comparatively shallow surface to the atmosphere; in the third place, the water in the well generally differs in a marked degree in the character or amount of the dissolved substances.

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[1] See the Jahresbericht der chem. Centralstelle in Dresden, vi. u. vii., 1878, p. 62.

[2] If the level of the water in the well were kept below the bottom of the river, the circle of influence might then be completed on the other side of the stream : if by so doing the tendency was to lower the level of the ground-water, and leave a vacuous space under the bed of the river, the river-water would work its way down to fill the gaps, and in that way water would be obtained from the stream.

In respect to the temperature it will be sufficient to give a single example: Waltham, Mass., takes its water-supply from an open basin near the Charles river. The basin is shallow, with a sandy bottom, and exposed freely to the sun and wind. During four days in August, 1876, the average temperature of the water in the river was 74° Fahr., and the water pumped from the basin averaged 62.8° Fahr. In February, 1877, when the river was frozen, the temperature in the basin was 48° Fahr. The bank is here only about 100 feet wide. That the water in the basin would approach that in the river in temperature if the water were drawn continuously through the gravel, we do not only believe on theoretical grounds, but know from experience. The city of Toulouse, in France, is supplied by a number of filtering-galleries in a gravel-deposit on the banks of the Garonne. The original gallery was built in 182–, at a distance of about 60 meters (200 feet) from the river. This furnished water acceptable in quality, but deficient in quantity; an increase of the length of the gallery failed to furnish a corresponding increase in quantity of water obtained. A second filtering-gallery, or rather series of connected wells, was constructed nearer to the river, at a distance, in fact, of only 10 metres. In this case the water obtained manifestly did come, in part at any rate, from the river; the water was somewhat turbid, and, what is very instructive, the passage through a bank of thirty feet, and admixture of course with some ground-water, failed to bring the water to anything like the uniform temperature of the other galleries. The temperature fell in winter to 2° C. (36° Fahr.), and in summer rose above 21° C. (70° Fahr.).* This gallery was therefore abandoned, and others constructed at a greater distance from the stream. These furnish water which is satisfactory, except when, in time of flood, the river covers the whole territory in which the galleries are built.

It must not be understood from the foregoing that the river in no case contributes to the supply of water obtained, for it often does and to a considerable extent. In such cases river-water may pass into the ground-water stratum for some distance along its banks, and thus make up the deficiency caused by pumping; often, however, the river may affect the level of the ground-water by virtue of its hydrostatic pressure, without actually mingling its waters with those of the well.

As a further illustration of the matter under discussion, we may consider wells which are near salt water. Sometimes, as we know, springs of fresh water issue from the sand even below low-water mark, and often wells of soft water are dug close to the water's edge. Even when there is no higher ground behind, the mere effect of the rain which falls upon the sand is to create a deposit of fresh water which crowds out or prevents the entrance of salt water. Darwin, in the voyage of the "Beagle," found this to be the case in low coral islands of the Pacific, close to the sea; and Amsterdam, the Hague and Leyden in Holland, obtain their water from collecting-canals in the sand-dunes which form an almost bar-

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[1] Daubisson: Annales des Ponts et Chaussées, 1838.

ren strip of country from 2 to 5 kilometres wide, and having only a few elevations of surface. Wells, near the salt water, often rise and fall, showing the influence of the tide, but the water remains fresh. This is easily explained, and may perhaps be made clear by the diagram, Fig. 14.

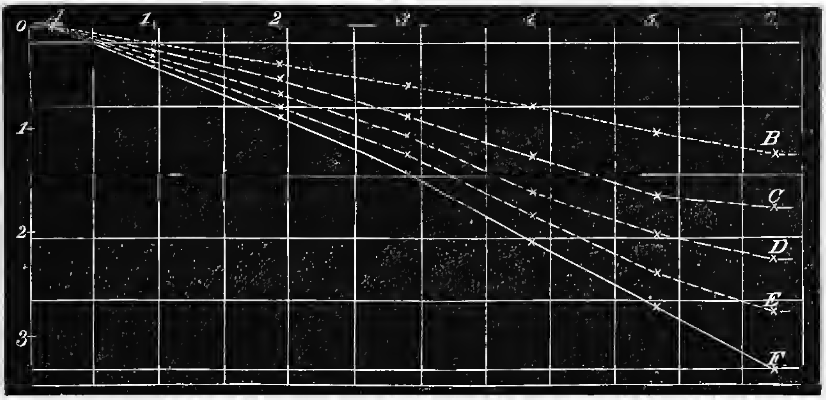

FIG. 14.

Let *A* be the most remote point at which the effect of the tide is felt, and *A B* the level of the water in the ground at high tide. As the tide falls successively to *B*, *C*, *D*, *E*, *F* the water will be at the levels indicated by the lines joining *A* with these points. When the tide rises from *F* to *E* the water level rises from *A F* to *A E* and so on. This diagram is the result of a particular experiment, and the results obtained in any case would depend upon the nature of the ground and the volume of the ground-water. The general character of the surface of the curves *A B*, *A C*, etc., would be essentially the same wherever there is any considerable movement of the ground-water. Under certain circumstances, especially if the ground-water supply be very small, there is a strip of ground into which the salt water finds its way at high tide and from which it drains at low tide. Wells sunk into this strip give only brackish water, and by pumping a large amount of water from a well near the shore, it is possible to cause the infiltration of salt water to a distance to which, under normal conditions, it would not penetrate.

Character of the Ground-Water.

In New England generally, and in some other parts of the United States, the ground-water, when sufficiently abundant, is of good quality; but in limestone regions it is often so hard as to be unsuited for use, and sometimes the presence of streaks or beds of clay makes it impossible to obtain clear water. Other substances which are present in the ground may render the water inferior, so that, as a rule, it is necessary to submit it to chemical examination. Wherever experiment shows that this method can furnish a supply of water suitable in respect to quality and quantity, it is to be recommended in preference to artificial filtration. The water in the collecting-well is usually quite free from organic matter, and generally contains a larger amount of mineral substances than the river-water. This difference almost always makes itself known by difference in "hardness" when the water is employed in steam-boilers or used for washing. To show this difference between the river-water and the neighboring ground-water, a few examples, selected from many, will suffice. Belgrand[1] gives the following figures with reference to certain French localities:

	Hardness in degrees.
Water of Rhone, at Lyons	16
Water of filtering-gallery at Lyons	17.94
Water of Loire, at Nevers	4.96
Water of collecting-well	20.70
Water of Loire, at Blois	7.76
Water of the gallery (which is beneath the bed of the river).	14.45

Sharples has found[2] that the water in the filter-gallery near Little Pond, Cambridge, Mass., contains nearly twice as much lime as that of the pond, and instances might be multiplied indefinitely. In the case of the Dresden water-supply, before alluded to, the river-water is harder than that obtained from the collecting-wells.[3]

In general, it may be said that it is practicable to procure a supply by the method of "natural filtration" only in localities where the ground-water is of good quality, free from possibility of pollution, and of sufficient depth and extent. Although there is less liability to pollution than in the case of small shallow wells sunk near dwellings, slaughter-houses, factories, or stables, it must be remembered that the ground-water is fed by the percolation into it of the atmospheric water, and that it is possible to pollute even a large body of water. This fact should be taken into account in choosing a locality for the collecting-wells.

There is great danger of overestimating the amount of water which can be permanently obtained from a chosen source of supply, unless the preliminary examinations are carefully conducted by persons who are fully conversant with such matters. It is always important to obtain information as to whether the supply must be drawn mainly from the rainfall over the region drained by the gathering well, or whether there is sufficient movement to the underground-water to practically increase this area. Where the level of the well is not below that of neighboring ponds or streams, it is generally the rainfall alone over the drainage area of the well which furnishes the supply. This admits of being calculated with

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[1] La Seine, etc., p. 463 et seq.

[2] Twelfth Annual Report of the Cambridge Water Board, for the year 1876, Boston, 1877, p. 30.

[3] Salbach: Das Wasserwerk der Stadt Dresden, 3 Theil, p. 7.

some degree of accuracy, if the general character of the land is known. Sometimes higher land, even at a considerable distance, may cause the yield to be greater than calculation would ascribe to the apparent drainage area. As a rule, the amount obtained from any such well is greater at first, as it requires time to drain out the water naturally occupying the territory which hereafter is to flow into the well, and in some cases it may be years before the well falls to what may be considered its normal delivery.

On Deep-seated Water as a Source of Supply.

Under this head we shall include, with natural springs and artesian wells, all wells which do not draw their supply from the ground-water proper, with the exception of such shallow wells as have been already considered.

Driven wells.—In many localities, a shallow well dug into the ground reaches the ground-water at no great depth, and if the well be carried to the bottom of the water-bearing stratum, an impervious bed of clay is reached, beneath which a second bed of gravel may be found, also water-bearing. This second supply of water may be of very different character from the ground-water proper, and under ordinary circumstances is less liable to pollution. A very common method of obtaining water from such a source, and one that is employed also in some cases in utilizing the ground-water itself, is that of "driven wells," "tube-wells," or, as they are sometimes called abroad, "American" or "Abyssinian" wells. These wells are made by forcing wrought-iron (or galvanized iron) tubes, such as are used for gas- or water-pipes, into the stratum from which the water is to be taken (see Fig. 15). The pipe is generally from 1¼ to 2 inches in diameter and is furnished at its lower end with a wrought-iron or steel point; above this point the pipe is perforated for some distance with holes to admit the water. The pipes are usually driven with a mallet (sometimes by means of a falling weight), and when the top of one tube has come to be at the surface of the ground, a second length is attached to it with a common coupling and the driving is continued until water is reached. In order for such a well to be successful the deposit into which it is sunk must be quite porous, so as to allow a free passage to the water; this is especially the case where the water is required in considerable quantities for manufacturing purposes or for town-supply.

Fig. 16 represents the method for town-supply adopted in Sycamore, Illinois. Here a well, lined with masonry, is excavated to the hard-pan, and through this hard-pan tubes are driven into the water-bearing stratum beneath, which is some seventy feet from the surface.[1] In other places the water is taken in part from the ground-water by a collecting-well, and in part from lower strata by tubes driven into the bottom of the well. This is the case at Attleborough, Mass.

Artesian wells.—An artesian well is a well which is sunk or bored

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[1] See Scientific American Supplement, No. 27, July 1, 1876.

through impervious strata, so as to reach a water-bearing stratum in which the water is under sufficient hydrostatic pressure to be forced to the surface, or nearly to the surface of the ground when the well is opened. The term is not generally employed unless the impervious strata are of *rock* and the depth of the well considerable. Thus a driven-well, 20 or 25 feet deep, would hardly be called an artesian well, even if the tube passed through an impervious stratum of *clay*. The general principle of the artesian wells is illustrated by the diagram, Fig. 17.

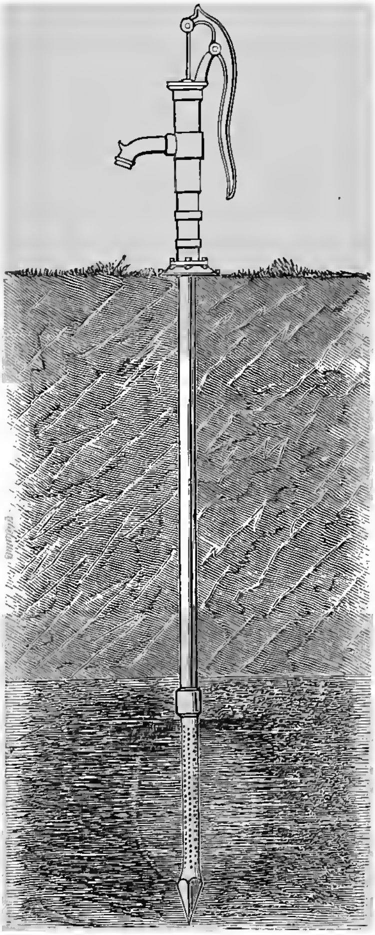

FIG. 15.

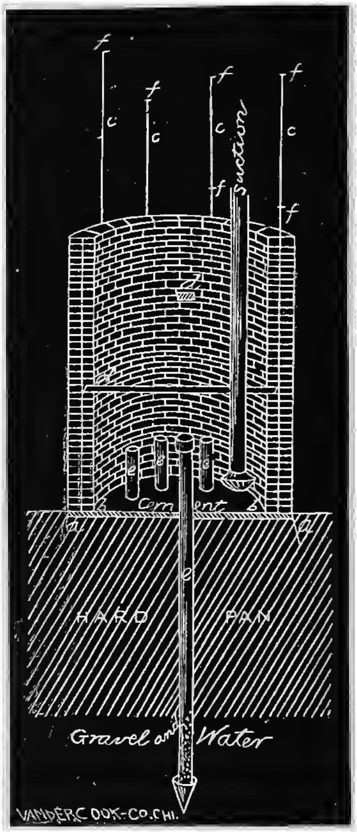

FIG. 16.—Sycamore water-supply.

The strata A B and C D are both impermeable to water, while K K is permeable. The water which falls upon the "outcrop" of the pervious stratum K K tends to sink to the lowest portion of the stratum, and gradually to saturate with water the entire deposit. The water at the lowest part of the basin is under a very considerable hydrostatic pressure, and when an opening is made through the superincumbent strata, by boring or otherwise, the water rises in the opening, and, in many cases, overflows. The height to which the water will rise depends upon the height of the line of saturation of the water-bearing stratum, at least in a measure; owing to friction, to the resistance of the air, and sometimes to leakage into the upper strata, the water will never rise to the height of its source.

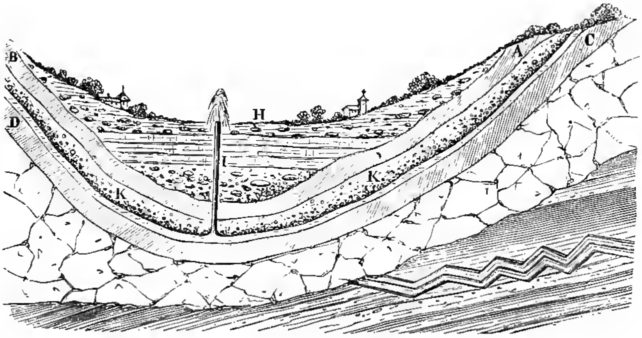

FIG. 17.—Principle of artesian wells.

It is not necessary that the permeable stratum in which the water is found should be of the nature of gravel; many wells draw their supply from rock strata. In the first place, all rock deposits are more or less fissured and seamed, thus affording passage for water, and, in some rocks, especially of limestone, the solvent and erosive action of the water wears channels and reservoirs. It is well known that limestone regions abound in caves and often in underground streams. Independently of seams and fissures, however, large quantities of water may be stored in rock deposits by virtue of the porosity of the rocks themselves. Some rocks are so compact that they can absorb but little, while others may take into their pores as much as one-third of their own bulk of water. This porosity is possessed not only by sandstones, but also by limestones, dolomites, and even by some varieties of shales and other argillaceous rocks.[1]

The source of the water obtained is not always traceable *directly* to the rain and snow which fall upon the surface of the ground. In some instances the formation is charged with water, which for ages has been confined in the stratum, the remainder of ancient seas or lakes. When an opening is made into such a deposit, the water is forced out, owing to the pressure of the water accumulated in other parts of the same stratum, or in communicating strata, but it may take a very long time to exhaust the subterranean reservoir. In some cases, near the sea, there may be commu-

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[1] For a number of experiments on the porosity of rocks, by T. Sterry Hunt, see Report of the Geological Survey of Canada, 1863–'66, pp. 281–283, or Hunt's Chemical and Geological Essays, Salem, 1878, pp. 164–167.

nication with the ocean, which may thus produce the hydrostatic pressure, but which may not contribute by its waters directly, or at least not for a long time after the well is opened. Some deep wells near the sea gradually become more brackish, probably from the fact that the purer water which originally filled the pores of the rocks, and perhaps subterranean reservoirs, is gradually exhausted, and other water—in this case sea water—comes in to replace it.

Of course there is very much with reference to the history and construction of artesian wells which is of interest, but which is not pertinent to the work now in hand. As sources of water-supply, no single general statement can be made with reference to the availability of artesian wells, because there are many circumstances which have a bearing on the character of the water.

One feature, which is common to most of the deeper wells, is that of the elevated temperature of the water. It is well known that the temperature of the earth increases somewhat regularly from the surface, and the effect of this is felt upon the waters which are obtained at considerable depths. The temperature of the water which flows from the widely-known well at Grenelle, Paris, which is about 1,800 feet deep, has a temperature of 27° C. (80.6° Fahr.). The water of an artesian well in Louisville, Kentucky, which is 2,086 feet deep, has a temperature of 76.5° Fahr.[1] There are, however, some wells which seem to form an exception to this rule, and different wells do not show the same rate of increase in temperature from the surface downward. Of course a water with a temperature of 80° Fahr., while admirably suited for some purposes, is not fit to drink unless artificially cooled.

There is another difficulty in the way of the use of artesian wells for domestic supply—namely, the large amount of dissolved mineral matter which the water from such wells is likely to contain. As almost all rocks are more or less soluble, we should expect that water which had traversed so great a distance under ground would be highly charged with mineral matter. Of course the character and amount of the dissolved substances depend upon the nature of the strata passed through. Sometimes the water is absolutely unfit for domestic use, although it may answer for extinguishing fires and watering streets or for irrigation. In other instances, the only difficulty may be that the water is too hard; if otherwise suitable, such water may, in some cases, be softened by a process which will be described later. (See page 284.)

Artesian wells are common the world over. In Egypt and in China there are such wells of unknown antiquity, and during the last fifty years great numbers have been sunk in Europe and in America. Of these the larger number have been sunk by private parties in order to obtain water for manufacturing or other purposes. The wells differ greatly in depth and in character of the water. In some cases the water is so strongly charged with common salt that it can be treated as brine; in other cases

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[1] Silliman's Am. Journ. Sci , [2] XXVII., p. 174.

the water contains a variety of salts, and is used as mineral water, while in still other cases a soft water fit for all domestic purposes is obtained. The following table includes facts with reference to a few of these wells:

LOCALITY.	Depth in feet.	Temp. in centigrade degrees.	Hardness.	Total dissolved solids.	Authority.
Birkenhead, Eng.	527	......	5.7	14.2	Rivers Pollution Commission.[1]
Birmingham, Eng.	300	10.2	15.8	31.3	
“ (another well)	400	10.8	15.1	19.4	
Bradford, Eng.	360	12.8	14.1	55.4	
Brighton, Eng.	1,285	9.9	4.4	35.4	
Liverpool (Bootle Well)	312	10.4	12.6	34.4	
London (Albert Hall)	401	......	5.6	61.7	
“ (Trafalgar Square)	383	......	5.9	83.4	
Grenelle, Paris	1,806[2]	27	..	14.2	Peligot, 1857.[3]
Passy, Paris	1,914[2]	28	..	14.1	Poggiale and Lambert, 1862.[3]
Boston, Mass.[4]	1,750	......	..	1,878.7	J. M. Merrick.[5]
Chicago, Ill.	700	14	..	......	(?)[3]
Louisville, Ky. (Dupont's Well)[6]	2,086	24.5	..	1,570.	J. Lawrence Smith.[7]
St. Louis, Mo.[8]	2,199	23	..	879.1	A. Litton, M.D.[9]
“ (Asylum Well)[10]	3,843.5	105	..	......	G. C. Broadhead.[11]

Several of the wells alluded to in the foregoing table are used for town-supply, such as the Bootle Well, Liverpool, and the well at Grenelle. One portion of the city of London is supplied by the Kent Waterworks Co., which furnishes upwards of 9,000,000 gallons daily, taken from wells in the chalk, in the neighborhood of the city. The water is quite hard, and hence ill suited for use in washing, but is clear and colorless and

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[1] Sixth Report of the Rivers Pollution Commission.

[2] Authorities differ as to the depth of these wells. Spon (Practice of Sinking and Boring Wells) gives sections, and states the depth of the well at Grenelle as 1,806′ 10″, and of the well at Passy as 1,923′ 8″.

[3] Ferreira: Hydrologie générale, Paris, 1867, p. 126.

[4] The Boston well is in the property of the gas-works, and is used only to quench the coke taken from the gas-retorts.

[5] Proceedings Boston Soc. Nat. Hist., XVII., p. 486.

[6] This well discharges 330,000 gallons of water in 24 hours, and throws it to a height of 170 feet. The temperature of the flowing water is 76.5° Fahr.; the temperature at the bottom of the well is 82.5° Fahr. The probable outcrop of the water-bearing stratum is at a distance of 75 miles and at an elevation of 500 feet above the mouth of the well.

[7] Am. Journ. Sci., [2] LXXVI., p. 174.

[8] This well, sunk at the sugar-refinery of Belcher and Brothers, at a cost of $10,000, furnishes about 75 gallons a minute of water highly charged with salts, and emitting a strong odor of sulphuretted hydrogen—utterly useless for the purpose of the refinery or for domestic supply.

[9] Trans. St. Louis Acad. Sci., I., p. 80.

[10] This well was not a success. The water was not fit for use, and did not rise to the top of the well.

[11] Trans. St. Louis Acad. Sci., III., p. 216.

wholesome. There would be no difficulty in softening the water; in fact, a portion of the supply, when some of the wells were in the hands of another company, was softened by Clark's process (p. 284) to the extent of 1,000,000 gallons (English) per day.

The last royal commission which has had to do with water-supply—namely, the Rivers Pollution Commission—speaks strongly in favor of abandoning the Thames and other rivers altogether, and thinks it feasible to obtain the entire supply for the metropolis from deep wells within a thirty-mile circle. That this could be done without decreasing the volume of the existing streams, which are in part supplied by springs from the same formation, they do not pretend; but they assert that the water thus obtained would certainly be wholesome; while the river water is, to say the least, undesirable as a beverage.

Liability of pollution.—Provided the well be protected from surface water, the liability to pollution is comparatively small. Generally the outcrop of the water-bearing stratum is at some distance from the point at which the boring is made; it may be several hundred miles. Fig. 18 represents the strata which form or underlie the Paris basin in which numerous artesian wells have been sunk. The horizontal scale is about 80 miles to the inch, and the vertical scale 2,000 feet to the inch. The wells are sunk into the lower greensand; and any impurities which enter the stratum at its outcrop—say at Verdun—have to travel underground nearly 200 miles before reaching Paris.

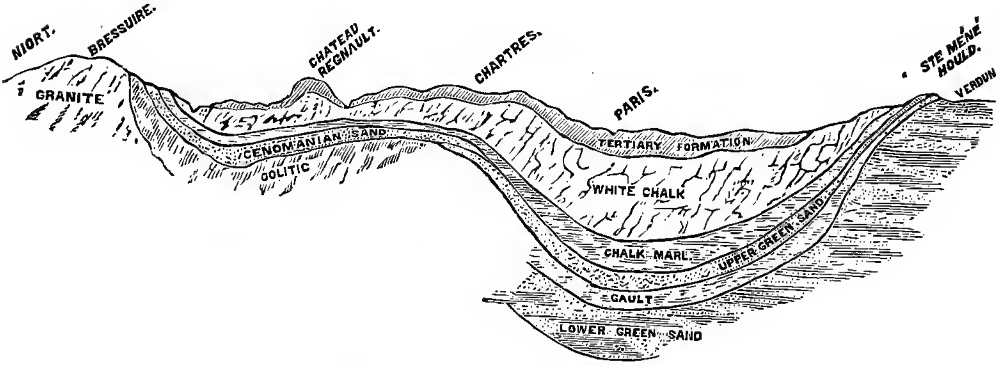

FIG. 18.—Geological section of the Paris Basin.

The water of deep wells does not, however, always have circumstances so much in its favor. If the well draws its supply, as many deep wells do, from what is an underground flowing stream, the liability of contamination is increased. That such underground streams do exist is evident from various facts. The total disappearance of some good-sized rivers into clefts of the rock, the emergence of full-grown streams in other localities, and the occurrence of flowing water in the larger caves, all show the same thing. Further evidence is afforded by observations which have been made on artesian wells. At Tours, in 1830, a well was perforated right through the chalk, when the water suddenly brought up, among other things, stems of marsh plants, with roots and seeds of the same, which were in such a state of preservation that they could not have remained more than three or four months in the water; and it is said that the seeds when planted sprouted and grew. It was supposed that the water must have flowed a distance of 150 miles during the time that these objects were immersed. At Reimke, near Bochum, in Westphalia, the water of an artesian well brought up from a depth of 156 feet several small fish, three or four inches long, the nearest streams being several leagues distant. The same thing has happened in other places, the fish not being blind, as those which inhabit subterranean caverns, but having perfect eyes.[1]

It will appear from these facts that, in projecting artesian wells for town-supply, it is important to know the geological character of the locality where the boring is to be made, and, as far as possible, the source of the water. Indeed, without a knowledge of the probable character of the particular locality, sinking a well is like investing in a lottery, and hardly justifiable as a municipal undertaking. It is true that many wells are sunk without the advice of competent authority, and some of them are successful; as a rule, they end in failure. The instance of the St. Louis, Mo., well, mentioned on page 257, where $10,000 was sunk in the well, is instructive in this connection.

Besides the possibility of direct communication with surface streams, there is danger of contamination from another source—namely, from the practice, which is in vogue in some places, of sinking wells, not as a means of obtaining water, but as a means of disposing of liquid refuse from manufactories, etc. Any well which does not overflow may be used as such an absorbing well (*puits absorbent*), and the amount which it will absorb may be approximately calculated.

Suppose we have a well in which the water rises just to the surface of the ground, but does not overflow, and that if 100 gallons per minute be pumped regularly, the water-level is lowered a distance of five feet; the same well may be made to absorb 100 gallons per minute by extending the tubing five feet above the normal water level. When the natural level of the water is much below the surface of the ground, an enormous amount of liquid may be disposed of for an indefinite time, provided the refuse be not of such a nature as to clog the pores of the absorbing stratum into which the liquid finds its way, or provided the well is frequently cleaned. There is a well of this kind at Bondy, near Paris, which is 74 metres in depth. Such a method of disposing of refuse should not be allowed, unless it is absolutely certain that the stratum into which the water finds its way carries naturally water which is totally unfit for use, and which will never be called upon for water-supply, and unless, further, there is security that the well does not pass through strata which contain water fit for

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[1] The foregoing facts are taken from Lyell's Principles of Geology, 11th edition, Vol. I., p. 390.

use. It is well known that it is very difficult to prevent the leakage of the water which rises in artesian wells into the upper strata, and this leakage often causes a very considerable diminution of the amount of water which would otherwise reach the surface.

The sinking of a pump-well and an absorbing-well into the same stratum[1] is like using the same river as a carrier of sewage and a source of water-supply. The intimate connection between artesian wells sunk into the same water-bearing stratum is readily proved; for, by the opening of new wells, there is often effected a very considerable diminution of the supply furnished by the older wells.

The opening of the artesian well at Passy caused a diminution to the extent of 30 per cent. in the amount of water flowing from the well at Grenelle, although the two points were about 3½ kilometres distant from each other. In Venice, seventeen wells were bored between 1847 and 1856. The increase in number of wells has decreased the amount supplied. Eight of the wells have ceased to flow, and of the others, one which delivered formerly 247 litres per minute gives only 76 litres, and the delivery of another has fallen from 220 litres to 67.[2] It thus appears, as we should expect, that there must be some limit to the yield of artesian wells, although that limit may not in all cases be approached in practice. Where a large demand is made upon any underground supply, the fact of such a limit becomes evident, either by the smaller yield of the wells or by the fact that to obtain the same amount of water the wells are kept pumped down to a lower point. This has often been noticed, among other places in the chalk of the London basin. "In 1838 the total supply obtained from the chalk near London was estimated at 6,000,000 gallons a day, and in 1851 at nearly double that amount, the increase being accompanied by an average fall of no less than two feet a year in the level to which the water rose. The water stood commonly, in 1822, at high-water mark, and had sunk, in 1851, to forty-five, and in some wells to sixty-five feet below high-water mark. This fact shows the limited capacity of the subterranean reservoir."[3] The water of artesian wells is subject to variation from time to time. Belgrand[4] found from 1857 to 1860 that the water of the well at Grenelle varied from 9° to 12° in hardness, and that it was harder after a dry year—*i. e.*, when the rainfall was less abundant. The published analyses of the water of the same well by Payne, in 1841, Boutron and Henry, in 1848, and Peligot, in 1857, show nearly the same total amount of dissolved matter, but considerable differences in the quantities of the various components. Some of the wells in Liverpool, England, show

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[1] This is exactly what is done continually, as far as the ground-water stratum is concerned, as we have seen (p. 242), and this is why shallow wells are unsafe.

[2] König: Anlage und Ausführung von Wasserleitungen u. s. w., 2te Auflage, bearb. v. Ludwig Poppe, Leipzig, 1878, p. 203. The original authority for this statement is not at hand.

[3] Lyell's Geology, 11th ed., 1872, Vol. I., p. 387.

[4] La Seine, etc., p. 99.

a continual increase in the amount of dissolved salts. Thus the well at Rainford Square contained, at different dates, as follows:[1]

	1867.	1871.	1878.	Rive Mersey.
Total solids	330	394.8	555.2	2,150.0
Chlorides	...	341.3	487.7	1,907.0

The quantity of water pumped has increased of late years, and there is drawn into the well a larger proportion of the water of the Mersey, which is 800 yards distant.

With reference to the storage of deep-well water, it has been found in many cases that there is great liability of vegetable growth when the water is exposed to air and sunlight, so that, if it becomes necessary to store the water before distribution, covered reservoirs must be used for the purpose, at least in warm climates.

In conclusion, it may be said that the chief advantage of artesian wells as a source of town-supply is in localities where the only water really fit to drink is stored rain-water or water from some very limited source. In such a case it is advisable, if possible, to procure in this way a supply of water which shall answer for most public uses and for many manufacturing purposes, although it is true that a good deal of uncertainty always attends the sinking of the first well which is bored in any particular locality.

On Springs in General.

Every one knows that springs differ greatly in the character of the water which they bring to the surface of the earth. Some furnish pure water devoid of peculiar taste, others furnish water highly charged with dissolved mineral substances, so as to be of noticeable and often of disagreeable taste; these are called mineral springs, and many of them are held to be highly valuable as medicinal agents. In some springs a single ingredient is the prominent one, as in brine springs, which are utilized in the production of common salt; in others there are a variety of substances coexisting in considerable quantities. In some springs the water is forced violently into the air by the gas (generally carbonic acid) with which the water is charged; others flow quietly and contain little or almost no dissolved gases. Some springs are cold and some are hot; some furnish an enormous volume of water, while others are of small account; some are constant, and some are intermittent.

With all this variety in the characteristics which appeal, many of them, even to the casual observer, there is a great difference in the causes to which we owe the appearance of the spring at all. We may illustrate a few of the conditions under which springs are produced.

Whenever a stratum of permeable material is exposed at a lower level than that at which, in another locality, it appears at the surface, springs

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[1] Isaac Roberts, F.G.S.: Paper read before British Association, Dublin, 1878.

are likely to be found. In the diagram, Fig. 19, the water falling upon the permeable stratum, C D at D passes downward, and may issue in springs at C, provided that A B is impermeable. When the material is homogeneous and gives free passage to water, the water may issue all along the line of the lower outcrop without forming any springs of great size. In this way the ground water, as has been already seen, contributes to the volume of rivers and lakes. If, however, the permeable stratum is of rock which is fissured, or if the water has formed channels by erosion or by solution, then springs of large size may appear at individual points. The figure also shows how a spring may issue at a point, such as S, the water passing up through a fissure which has been formed in the deposit overlying the water-bearing stratum. Again, if a trap-dyke intersect the various strata, as shown by the dotted lines in the figure, the water falling at D and accumulating in C D would meet an obstacle in this dyke and the water would appear as springs at S. Not unfrequently water

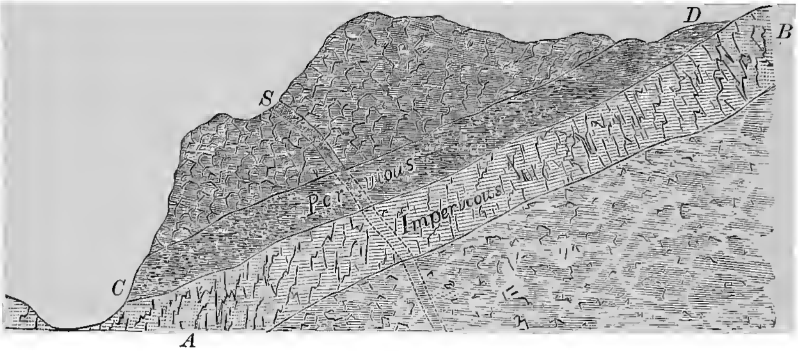

FIG. 19.

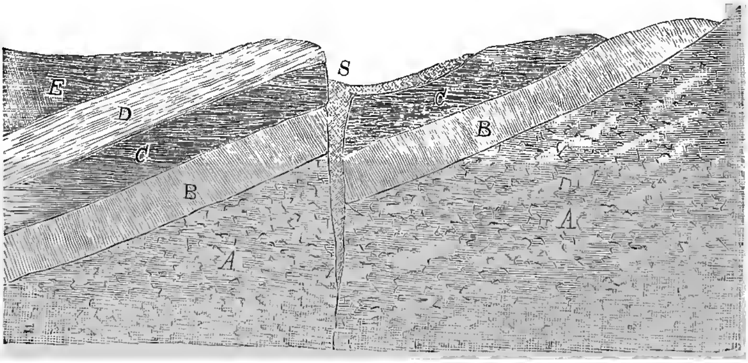

FIG. 20.

A, A.—Laurentian rocks.
B, B.—Potsdam sandstone.
C, C.—Calciferous sandrock.
D.—Trenton limestone.
E.—Hudson and Utica shales.
S.—Saratoga Valley.

rises to the surface of the ground from great depths, the springs then resembling artesian wells except that the orifice or fissure through which the water issues is natural and not artificial. Sometimes the appearance of a spring at the surface of the ground is due to what geologists term a "fault," as illustrated by Fig. 20.

This figure, according to Professor Chandler, represents the conditions which give rise to the mineral springs of Saratoga, N. Y. Here there has been formed a fissure along the line of the valley, and the strata, which were once continuous, now are at different levels on either side of the fault. The water of the Potsdam sandstone on the right of the fault, meeting the less pervious underlying rock, would tend to rise to the surface, and, if not carried off by the pervious strata as it comes in contact with their upturned edges, would appear as springs. A number of the Saratoga springs have been brought to the surface by the boring of artesian wells and tubing them properly so as to keep out the water coming from nearer the surface and to prevent the leakage of the mineral water.

On Springs as a Source of Water-supply.

Such springs as do not rise from too great a depth in the earth's crust are of nearly uniform and comparatively low temperature, and in summer are cool and refreshing. There is no doubt that, as sources of water-supply, springs stand in the first rank, although they are by no means to be considered the only suitable sources. Their advantages are their uniform temperature and their comparative immunity from pollution; their disadvantage, as a class, is their liability to contain an objectionable amount of dissolved solid substances.

In Germany there has been a great feeling in favor of spring water, and, at the Danzig meeting of the German Public Health Association (1874), a resolution was passed, after much discussion, to the effect that "spring water alone, either that coming to the surface naturally, or reached by sinking properly constructed and properly protected wells, is the only admissible source of water-supply." The next year this dictum was altered, so as to state that spring water, ground water, and filtered river water may fulfil the conditions required of a good drinking-water.

As already said, spring water is liable to contain an objectionable amount of mineral matter, but is usually quite free from organic substances, and although it is somewhat less liable to contamination than the water of deep wells, for purposes of water-supply the same considerations are involved in both cases. Natural springs often occur under such circumstances that the water may be delivered by gravitation, which is of a certain advantage.

One of the most recent instances of the utilization of spring water on the large scale is in the case of the new water-supply of Vienna, opened in the fall of 1873. Here the water is obtained from two springs which issue from the spurs of the Alps, one at a distance of 90 kilometres, and the other of about 70 kilometres from the city. The waters of the two aqueducts are united some 66 kilometres from the city, and flow together for that distance. The works were calculated for a maximum supply of 141,500 cubic metres per day, the average necessary amount being fixed at 92,800 cubic metres. Practically, after the opening of the works, it was found that the amount obtained fell short of the estimates, and that it would be necessary to extend the work so as to include other springs. It is to be said that it is proposed not to rely for all purposes upon the spring water, but for watering streets, flushing sewers, etc., to use the water of the Danube taken directly from the river, or that obtained by a process of "natural filtration."

ON THE ARTIFICIAL IMPROVEMENT OF NATURAL WATER.

Soft spring water, ground water, and sometimes deep spring water, are suitable for domestic supply, just as they are obtained from the natural sources. All other sources of supply are liable to leave something to be desired in the quality of the water. While no method of treatment can afford perfect security if a water is polluted by sewage, there are several processes by which a natural water may be improved and rendered more fit for domestic use. We shall consider:

1. Sedimentation (and aëration).
2. Filtration on the large and on the household scale.
3. Clark's process for softening hard water.
4. Other (chemical) processes.

Sedimentation and Filtration.

These processes, which are in the main mechanical, are particularly needed in the case of water taken from running streams; for, as has already been stated, and is indeed well known, rivers generally carry more or less of floating material. Much of this floating or suspended matter is of so coarse a character as to be readily intercepted by wire strainers, or other such devices; but a considerable amount is so finely divided as to require more elaborate arrangements for its removal. Before discussing the matter in detail, it is important that there should be in the mind of the reader a clear idea as to the use of certain terms which have been already employed, namely, the terms "in solution" and "in suspension." At the same time it will be important to distinguish between the terms "clear" and "colorless," which are by no means synonymous.

The accurate use of the terms can probably best be made plain by illustrations. If, for instance, we put some common salt into a quantity of water, after a time the salt disappears, the ultimate particles being distributed through the water, so that they are no longer distinguishable by the eye, even aided by the most powerful microscope: the salt cannot be removed by simple filtration; and, although the solution is somewhat less mobile than water, it is still transparent. This is a case of solution. Suppose, instead of the salt, we take a quantity of blue vitriol (sulphate of copper). The phenomena would be similar; but the blue color of the compound would show itself in the solution. If the solution were saturated, *i. e.*, if the water had dissolved as much as it could, the transparency of the liquid would be diminished on account of the depth of color: it would be easy, however, to take a very thin layer of the solution and satisfy one's self of its transparency. Such a liquid is colored, but is also clear.

Suppose, now, we take some clay, shake it with water, and then allow it to settle. The grosser particles will subside to the bottom of the vessel, but the finer particles will remain in suspension. Very finely-divided clay will refuse to settle for weeks, and sometimes even for months. In such cases the liquid appears somewhat turbid and opaque; and, although the individual particles are too fine to be readily removed by ordinary filters, and too small to be distinguished as particles by the eye, still the clay has not dissolved; and the very turbidity or opacity of the liquid shows the presence of solid particles, although they are extremely minute. Such an appearance is not to be described as "being colored," although finely-divided clay and other material may be suspended in a liquid which does of itself possess a distinct color. One often meets with the expression, and that too in standard works, "the water is discolored by clay," when really it is a question of a colorless water carrying particles in suspension. The water in many streams is at seasons highly colored by vegetable extractive matter in solution; while the water may at the same time be perfectly clear and transparent. On the other hand, our pond waters are often decidedly green; but simple filtration gives a colorless water, and shows the green color to have been due to particles of green (vegetable) matter which were suspended in the liquid.

Sedimentation.—Much of the matter which a running stream bears along in suspension is of higher specific gravity than the water itself; and if the water is allowed to stand quietly in basins or reservoirs, the greater portion of the suspended particles will subside. Many lakes illustrate this fact; the stream which enters at the head of a lake may be very turbid, while the outlet of the lake is bright and clear. The Romans, in their water-works, recognized the advantage of subsidence. Precautions were taken in many cases at the sources themselves to insure, as far as possible, freedom from turbidity; and there were constructed at intervals in the aqueducts what were called *piscinæ limariæ.* Fig. 21 represents one of these *piscinæ,* through which the water of the Anio Novus passed at its entrance into Rome. The direction of the water is shown by the arrows. The channel of the aqueduct coming at a tolerably high level entered the right-hand upper chamber. From this chamber the water passed (possibly over a large waste-pipe) into the chamber beneath, and thence into the left-hand lower compartment through perforations in the wall. Through the roof of this chamber there was a hole, and the water passed upward, of course finding the same level at its exit as that at which it entered the *piscina.* By the aid of sluice-gates the water could be passed through the two upper compartments without entering the lower ones. Access was obtained by an opening to the chambers beneath, and the mud was from time to time cleaned out. These *piscinæ* have been spoken of as "filtering-places;"[1] but this is incorrect.

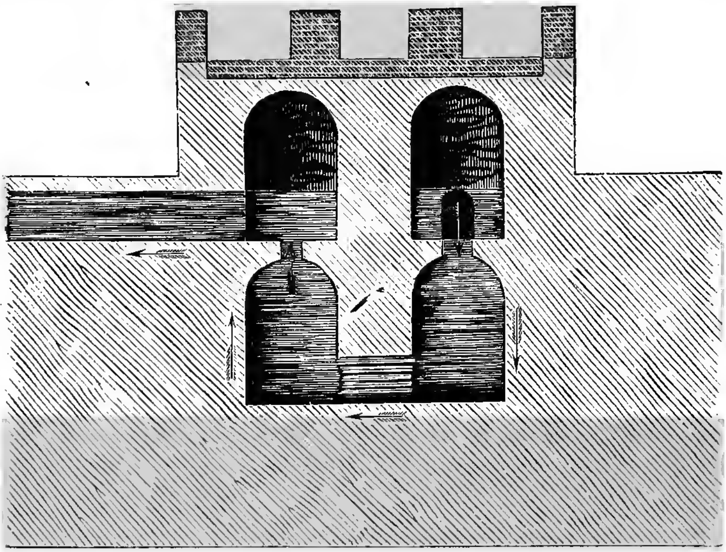

FIG. 21.

The openings in the wall between the two lower chambers were small, and may, as Parker suggests, have been covered by some sort of a grating; but it is evident that it would be impossible to insert in the course of a stream of the size of that which flowed in the aqueduct anything which could act otherwise than as a coarse strainer. No doubt the efficiency of these *piscinæ* was due to the opportunity given for subsidence.

In many modern works the water of a turbid stream is allowed to stand in settling-basins for a few hours or days. Hamburg, on the Elbe, St. Louis, on the Mississippi, submit the river water which they use to no other treatment. As a means of purification, such a process is, as a rule, utterly inadequate. Even as a means of *clarification*, subsidence alone has proved insufficient. In spite of the *piscinæ limariæ*, we learn that the water often reached Rome in a turbid condition,[2] and, in modern cities, where reliance is placed on subsiding basins alone, the water is frequently supplied in an objectionable condition, and the water-takers are driven to the use of household filters.

The writer had recently an opportunity to inspect some of the

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[1] The Archæology of Rome, by John Henry Parker, C.B., Part VIII.: The Aqueduct. See p. 71. See also Popular Science Monthly, May, 1877, p. 31.

[2] Frontinus: De aquæductibus urbis Romæ, § 15: "Sic quoque, quotiens imbres superveniunt, turbida pervenit in urbem." Frontinus was superintendent of the aqueducts (*curator aquarum*) under Domitian and Nerva, and died A.D. 107.

water-mains in Hamburg, which were being removed in the course of some repairs. The pipes contained a quantity of sedimentary matter, and the interior was almost literally *lined* with masses of mussels. It is not surprising that the condition of the water is the subject of a great deal of complaint. At Altona, however, which is situated a few miles lower down on the same stream, the Elbe, and where the water is filtered, it is stated by the chief engineer and superintendent of the water-works, Herr Kümmel, that the pipes are perfectly clean, and that there is no animal or vegetable life in the filtered water. While sedimentation alone is unsatisfactory, the process is of great value, and often practically indispensable as a preliminary to successful filtration.

Aëration.—Where a natural water is stored in open basins or reservoirs in order that the suspended matter may subside, other actions are at the same time concerned, and notably the action of air and light. Although, as has already been seen, the storage of surface water in shallow reservoirs is often attended with great disadvantages, owing to the heating of the water and to the growth of minute vegetable organisms, there are, on the other hand, advantages attending the storage of some kinds of water. A water which is colored by dissolved vegetable matter, as are the streams which flow from marshes or peat-bogs, loses a sensible amount of color, and the effect is the more marked as the reservoirs increase in size and, other things being equal, in depth. This action is very marked in many natural ponds. Take, for example, Loch Katrine, in Scotland, from which the water-supply of Glasgow is taken. Into this lake there enter a number of streams which are so charged with the extractive matter of the peat as to be quite brown in color. The color of the water of the lake, however, where it enters the conduit, is scarcely noticeable, and the water in the city of Glasgow is ordinarily clear and apparently colorless.

The loss of color is usually regarded as the result of the action of sunlight; but as such loss of color is usually accompanied by the deposit of more or less sediment, even when the water has seemed clear, it is not improbable that chemical action takes place, in which the oxygen of the air plays a part.

The effect of the oxygen of the air as a means of purification in the case of running streams has already been discussed. It has been proposed to aërate artificially the water of storage reservoirs and other water used for domestic supply, and it is no doubt of advantage in the case of small uncovered reservoirs to arrange the outlet and inlet so as to promote a continual circulation of the water and to avoid stagnation; beyond this it is doutful if very much is to be gained by artificial exposure of water to the air.

A water which contains no dissolved gases is flat and insipid, so much so that where distilled water is prepared for drinking, as, for instance, on shipboard, it is necessary to aërate the water. There is, moreover, no doubt that the oxygen gas which any water dissolves from the air when it is in contact with it plays an important part in the destruction of organic matters derived from various sources. But this oxidizing action has been overrated, and no artificial process of aëration can suffice to render pure the water from a contaminated source. Water absorbs a certain amount of oxygen rather freely, and with proper circulation in pipes and reservoirs there is nothing to be feared in the way of a lack of aëration of a good water. Even water from deep springs which issues from the ground nearly, or in some cases absolutely, free from oxygen, soon acquires its proper amount. It is true that stagnant water ponded over decaying vegetable or animal matter loses its oxygen; but remove the water from over the deposit and oxygen is reabsorbed.

Allusion may be made to a process of purification, said to be in use on the River Neva, at St. Petersburg, for the purpose of rendering the river water suitable for the manufacture of bank paper.[1] The apparatus consists of several troughs, placed step-wise one above the other. Each trough is divided longitudinally by a partition, which does not reach the bottom, into two compartments. The inner or rear division is covered with wire-gauze, and receives the water as it flows from the step or trough above; from the outer compartment the water falls some two feet on to the gauze of the step below. The total area of the gauze is 420 feet, and it has fifty meshes to the inch. The water is treated to the amount of 100,000 cubic feet in ten hours. The water, as it begins its descent through this apparatus, is said to appear clear and pellucid, but before passing through two sheets of gauze it becomes turbid and deposits a black scum on the wires, which thus require frequent cleaning. The tanks which receive the water are constantly covered with a thick scum, and the water is filtered through sand and gravel before being used. It is a question how far the action in this case is due to chemical, and how far to mechanical action, to the "flocculation" of the fine suspended particles as a result of the agitation of the water. Probably the latter action plays an important part.

Filtration.—By a properly conducted process of filtration it is possible to effect thorough clarification. All floating particles visible to the unaided eye may be thus removed; some substances, however, much more readily than others.

The filtration of water on the large scale has been practised in England and on the continent for years, and filtration works are now considered, as a matter of course, a part of any scheme for the introduction of water from a running stream. In this country very little has yet been done in this direction. In the year 1866 James P. Kirkwood, C.E., went to Europe in the interests of the city of St. Louis, to study the clarification of river waters used for the supply of cities. He made an elaborate report[2] on the subject, giving details of European practice and plans for filtering-beds for St. Louis.

St. Louis has not yet adopted any system of filtration, but several

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[1] Proceedings Inst. Civil Engineers, XXVII., 1867–'68, p. 46: an account given by Mr. C. E. Austin.

[2] Kirkwood: Filtration of River Waters, New York, Van Nostrand, 1869.

other cities of smaller size have done so with more or less success: namely, Poughkeepsie, N. Y., in 1871; Hudson, N. Y., in 1874; Columbus, O., in 1874; Toledo, O., in 1875.

Up to the present time no filtering material has proved practically available on the large scale, except sand. Various attempts have been made to use other substances, but hitherto without marked success. We will, therefore, consider the general features of the process of sand-filtration as practised at home and abroad.

Filter-beds, as usually constructed, are water-tight basins, some ten feet or more in depth, the sides built of masonry, and the bottom puddled or made of concrete, or paved with brick and cemented. The area may be from 20,000 to 50,000, or in some cases even 150,000 square feet. In building up the filtering-bed, provision is first made for the ready collection of the water by constructing upon the floor of the basin drains or channel-ways of stone or brick laid dry; then follows a layer of broken stone, the fragments being three or four inches in diameter. This is succeeded by gravel screened so as to be of uniform size, a layer of coarse being followed by one or more layers of finer material; upon the gravel rests sand, likewise separated into layers of uniform size. The exact thickness of the different layers, and the extent to which the separation into the different sizes is carried, are subject, of course, to considerable variation. The object of the care bestowed in arranging the material of the filters is to prevent the fine sand from finding its way into the drains, and, at the same time, to have such a body of water below the filtering surface as to insure the gradual and uniform passage of the water from the surface to the drains without the creation of actual currents or streams.

The accompanying figure, Fig. 22, represents a section of the filter-beds at Poughkeepsie, N. Y., which are constructed on the English model. There are two filter-beds, each 200 × 73½ feet in plan and 12 feet deep, built with vertical walls: each has, therefore, 14,700 square feet of filtering area. The six feet of filtering materials, beginning at the top of the bed, are disposed as follows:

24	inches	of sand.
6	"	¼ inch gravel.
6	"	½ "
6	"	1 "
6	"	2 inch broken stone.
24	"	4 to 8 in. "
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Total, 72 inches.

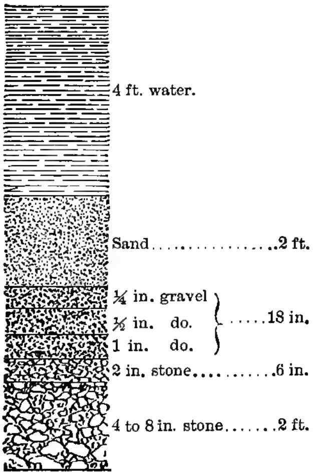

FIG. 22.—Section of Poughkeepsie filter-bed.

The water stands several feet deep over the surface of the sand, and is allowed to flow down through the filter at such rate as experience shows to be most advantageous. Naturally, when the sand is clean, a greater quantity of water will pass in a given time than when the sand has become clogged; practice differs as to the maximum rate; but it is seldom over six inches, vertically, per hour, and often less. At the rate mentioned, each square foot of surface would deliver 12 cubic feet (or 89¾ United States gallons) per day.

When the beds become clogged, so as no longer to filter with sufficient rapidity, the water is drawn down to from 12 to 24 inches below the upper surface of the filtering-beds, or is drained away entirely, and the upper layer of sand, for a depth of one-half or three-quarters of an inch, is removed. When by successive parings the thickness of the sand has been considerably reduced, that which has been removed is washed and replaced so as to restore the original thickness, the waste of washing being made up with fresh sand. In the worst stages of the English rivers a filter-bed has to be cleaned once a week, rarely oftener. When the rivers are free from turbidity, cleansing may not be necessary more than once a month, or in some cases once in two months. Cleaning of the filter-beds in winter is attended with considerable inconvenience. The European practice, in locations where the ice freezes to any thickness, may be learned by the following quotation from Kirkwood's account of the Berlin works:

"The ice forms upon the filter-beds 15 inches thick, and sometimes, though rarely, 24 inches thick. To protect the enclosing walls of each filter from damage, the ice is kept separated from the walls, 6 to 12 inches, by attendants appointed to that duty; and, so long as the cake of ice is kept floating in this way, the masonry is safe from any danger by its thrust."[1]

It is becoming customary in Germany to cover the filter-beds, and thus to allow the filtration to take place the same in winter as in summer, although it is not necessary to clean the beds as often during the cooler part of the year. It would seem that, in our climate, the filter-beds should always be covered, not only to prevent the formation of ice in winter, but also to prevent, in some measure, the heating of the water in summer to a high degree, and the consequent encouragement of vegetable growth.

While it is, in general, true that the upper layer of sand does most of the work in intercepting the various floating matters in the water, it does not do the whole under the conditions which occur in ordinary practice. Examination shows that the sand is somewhat affected to a greater depth, and it may occasionally be necessary to renew all the sand. The very fact that in all actual works there are times when the water is imperfectly clarified, shows that the interior of a sand-filter must become more or less fouled. The depth to which the sand becomes sensibly fouled depends upon several conditions, and mainly, in the case of any given water, upon the

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[1] See Kirkwood's Filtration of River Water, p. 114. Since Kirkwood's report was made, the Berlin works have been much extended, and a portion of the filters are now covered.

rate of flow, upon the *head* under which filtration takes place, and upon the frequency with which the beds are cleansed.

The *head* under which the water is filtered varies at any works according to the condition of the sand. The clear-water well is generally so arranged that the height of water in it can be lowered at pleasure; and the head under which the water is filtered is the difference between the level in the bed and in the clear-water well, as may be seen in the accompanying cut, where the head is measured by the distance between *a* and *b*. While the beds are clean, a difference of from 9 to 12 inches suffices to cause a proper rate of flow; when they become clogged a much greater pressure is required. There is a limit, however, beyond which it becomes undesirable to increase the head. The greater the pressure, the more densely does the sand become packed; and in cleaning the beds, after scraping off a thin layer of foul sand at the top, the usual custom is to loosen the sand with forks to the depth of some inches. The best authorities, however, regard this as unadvisable; and it is a sign of bad management when the water is filtered under such a head that this operation is rendered necessary. The increase of pressure, too, drives the impurities to a greater depth into the sand; and there is liability, in filtering under too great a head, when the bed has become somewhat clogged, especially if the water in the clear-water well is allowed to fall below the level of the sand, that the water will force its way through the sand where the clogging material offers the least resistance, and thus pass downward irregularly and in actual streamlets.

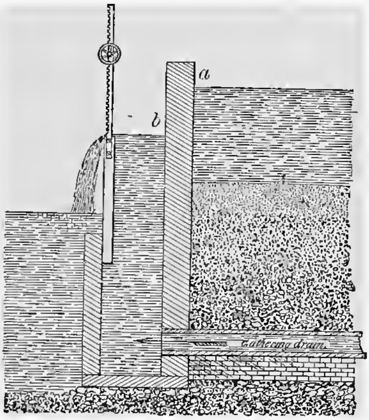

FIG. 23.

In some places the filter-beds are cleaned by forcing the filtered water backward through the filtering material, and stirring up at the same time the upper part of the sand-layer. The dirty water is allowed to overflow and to run to waste. This method presupposes an abundance of water and the ability to command the necessary pressure, and is hardly to be recommended. It is practised at Zürich, in Switzerland, where the water filtered is practically spring water rendered turbid by clay or other mineral matter.

Object and Results of Filtration on the Large Scale.

Having considered the method of filtration in common use, we may now profitably inquire more closely into the object which it aims to accomplish, and the results which are actually obtained.

Filtration, in its strict sense, is simply a mechanical operation, and directs itself to the removal of such substances as are carried in suspension in the water. The suspended matter, which by its presence in our water-supplies makes filtration desirable, is somewhat various in character. Sometimes the suspended matter will settle quite readily by virtue of the comparatively high specific gravity of the particles, as will be the case of the mineral matter consisting of sand, mica, etc. Such substances are readily removed by filtration; but we have seen that it is generally more economical to subject the water to a process of sedimentation first, and settling-basins are quite universally regarded as a necessary preliminary to successful filtration. It is evident that without sedimentation a slower rate of filtration must be employed, and the sand must be cleaned more frequently. If the suspended matter is clay, it may obstinately refuse to settle; in this case it is almost impossible to filter the water slowly enough to obtain good results if the turbid water without previous sedimentation is put directly upon the filter-beds. Even with sedimentation the result is not always as good as might be desired, and in works which are actually in operation it not unfrequently happens that imperfectly clarified water is delivered to consumers.

With respect to the minute vegetable organisms which occur in surface waters, there is no difficulty in removing them completely by sand filtration, although of course the filters become rapidly clogged. This clogging is aided also by the development upon the beds themselves of confervoid growth, which in uncovered beds become so abundant and vigorous as to form a sort of carpet on the surface of the sand, which can be raked off in coherent sheets or rolled up.

We are come now to consider more particularly the action of a sand-filter. On the suspended matter, the action, although simple, is twofold. In the first place, particles too large to pass into the interstices of the filter are arrested at the very outside; in the second place, and with regard to finer particles, the process is one of sedimentation and adhesion. It is well known that a turbid liquid will deposit sediment, not simply on the bottom of the vessel in which it is contained, but also upon the sides. In a sand filter, as the water passes slowly downward, not in veins, but by percolation, the minute particles of suspended matter are attracted to and deposited upon the walls of the numerous vessels which are formed by the void spaces between the grains of sand. This is true even when the material of the filter is very coarse. If muddy water be passed *slowly* through a bed of shingle or broken stone, it will clear much more rapidly than if the subsidence takes place in an unobstructed basin.

While it is true that the action of a sand-filter is exerted chiefly on the substances which are in suspension, it is also true that some effect is produced upon matter actually in solution. This effect has been very much exaggerated; and yet there is no doubt that, if properly managed, sand filtration is competent to remove an appreciable amount of dissolved organic matter. The action may be explained in two ways. In the first place, most porous substances possess the power of removing certain kinds of organic matter by something which may be called *adhesion.* The absorptive power for any substance is limited and soon reached, and the substance thus removed may by appropriate means be again brought into solution. Quartz sand, as we should infer, possesses the power to a slight degree only. The second method, by which dissolved organic matter is removed in the sand-filter, is by oxidation. The substance is actually burned more or less completely, in part by the oxygen held in solution in the water, and in part by the air entangled in the interstices of the sand. Although in filling the beds with water, great care is taken to displace the air gradually, and as completely as possible, there must always some remain in the concavities of the individual grains of sand and otherwise entangled. The extent of the action of a sand-filter in this direction depends not only on the thickness of the filtering medium, and the rate at which the filtration takes place, but also, and in large measure, upon the frequency with which the filter is cleansed. The cleansing of the filter not only removes the accumulation of organic matter, which if allowed to remain would tend to injure the water, but also involves the aëration of the sand.

Many analyses have been made to ascertain the effect of sand-filtration upon the water filtered. In some cases the oxidation alluded to is sufficient to determine an appreciable decrease in the amount of dissolved organic matter which gives color and unpleasant taste to the water. In view of what is actually accomplished in existing works, it seems to be best to regard the removal of color and unpleasant taste as incidental and likely to vary very much according to the condition of the filter. If a sand-filter removes completely all suspended matters without allowing the matter at first removed to contaminate by its decay the water filtered subsequently, it may be regarded as successful.

In order to secure success in the management of any scheme for the filtration of water on the large scale, the works should be under the management of a person of intelligence and of some education and experience. The filter-beds should be properly constructed, especial attention being given to the sand employed, and should be cleaned with sufficient frequency. Settling-basins of sufficient size will generally be necessary, and, for the best effect, the filter-beds should be covered, and the filtered water delivered at once to the consumers, or, if stored, it should be stored in covered reservoirs of small size, which can be readily emptied and cleaned if occasion require.

The covering of the filter-beds is a great advantage, as has already been said; the covering of the clear-water basin is to be regarded as a necessity, especially in case of all waters which are liable to considerable vegetable growth. It would seem that the spores of the algæ are not removed by the passage through sand; at any rate, if the filtered water be stored in a reservoir exposed to light, the algæ develop themselves anew, and the advantage once gained is lost. It is, however, confidently asserted that, if the water after filtration be stored in *covered* reservoirs only, no growth will make its appearance. This has certainly proved to be the case in Berlin, Altona, and other places in Germany, and in several localities in England as well.

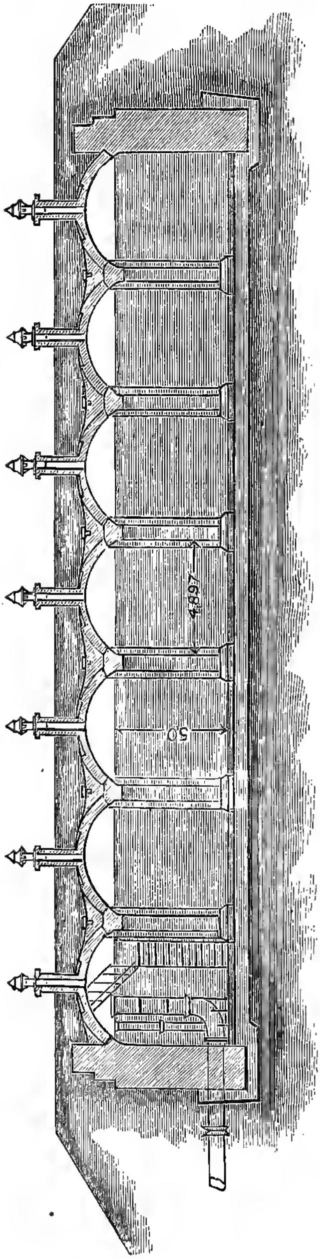

FIG. 24.—Section of storage reservoir, Dresden.

In Europe it is usual to cover all distributing reservoirs and sometimes the filter-beds by arching them over with masonry or brick-work and then covering with earth. Fig. 24 represents a section of the reservoir at Dresden, Germany, which has a capacity of 19,200 cubic metres. Fig. 25 is a suggestion from Fanning's Water-Supply Engineering of a less expensive form of covering. This would be somewhat less serviceable as a means of keeping a uniform temperature on the beds, and, as far as known, no such coverings are in actual use.

As to the extra expense of filtering the entire water-supply of any town, much will depend upon the extent of the works. From figures furnished by Mr. The. W. Davis, of the Pougkeepsie Water-Works, the cost at that place appears to be from $2.50 to $3.50 per million gallons filtered, but with larger works the running expenses would properly be less.

Household Filtration.

Of household filters, patented and unpatented, there has been and is the greatest variety, both in form and material. Many sorts of porous stone, sand, powdered glass, bricks, iron in turnings, and other forms, vegetable and animal charcoal, sponge, wool, flannel, cotton, straw, saw-dust, excelsior, and wire-gauze—these are some of the substances which are used for the purpose.

There are certain fundamental requirements which a filter must satisfy in order to be considered suitable for household use. In the first place, it must be made of a material which cannot communicate any injurious or offensive quality to the water which passes through it; second, it must remove all suspended particles, so as to render the water bright and clear; third, it must either be readily cleaned, or the filtering material must be arranged so as to be readily renewed. In addition to these *requirements*, it is of great advantage if the filter is able to remove a noticeable amount of the dissolved organic matter which most waters contain.

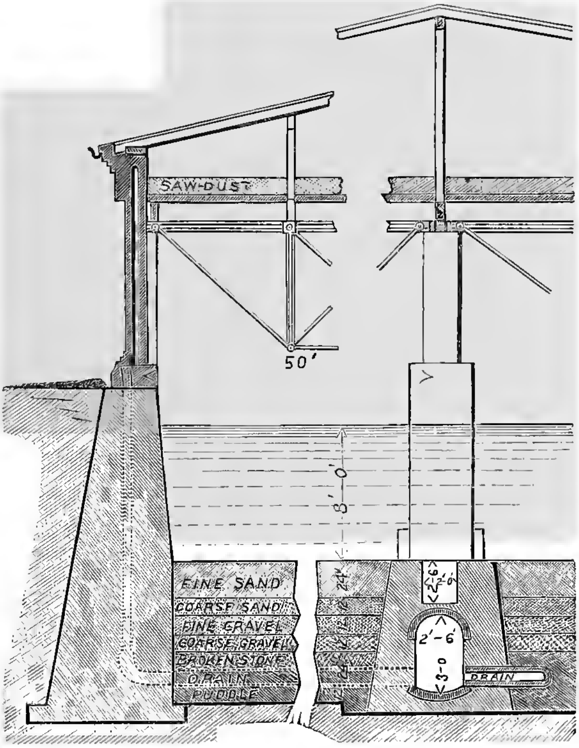

FIG. 25.

Allusion has been already made to the fact that the action of a filter is either mechanical or chemical. There is a mechanical action, by virtue of which solid particles which are too large to pass the pores of the filter are arrested: other particles are drawn by a force of adhesion to the surface of the particles of the filter, and are thus removed. This property of adhesion, if it may be so called, is sometimes exerted to such an extent as to remove substances which seem to be completely dissolved, without, however, producing any apparent chemical change in them. The substances so removed may be again by proper means recovered and brought into solution. There is also an unmistakable chemical action, by virtue of which some substances are destroyed, or rather are converted into new compounds. This action is mainly due to processes of oxidation which take place, in part at the expense of the oxygen which is contained in the solution, and in part at the expense of the oxygen mechanically entangled in the pores of the porous substance employed. Different porous substances differ very much in this respect. A mass of clean quartz sand can produce little effect, while animal charcoal possesses such a power in this direction that it is used in the arts to decolorize colored liquids.

Household filters may be divided into three classes: first, those of small size, intended to be attached to the faucet, where the water is brought in pipes either from the service-mains of a general supply, or from a tank in the building; second, the portable filters designed to occupy a more or less permanent position, and to be filled with water, either by a ball-cock or other similar arrangement, or by means of smaller supplies continually renewed; third, the more permanent and fixed devices which are inserted or built into underground or other cisterns.

In the case of filters of the first class, *i. e.*, those which are made to be attached to water-taps, it is not practicable to require anything more than that they shall act as mechanical strainers and arrest all suspended substances which may be in the water. There is no material known which can be introduced into the small space of a tap-filter and accomplish any real *purification* of the water which passes through at the ordinary rate of flow.

Of all the patent contrivances which have been proposed, there is probably, after all, none better than the form which has been in use for many years, which is filled with clean quartz sand, and is capable of being readily reversed and thus cleansed. Even animal charcoal in the quantity which admits of being readily attached to a faucet has no advantage over such a filter.

Sponge is very efficient as a strainer, and admits of being compressed into small compass. There are several forms of sponge-filters which may be screwed upon a common tap. If the sponge be removed and washed with hot water every few days, these filters serve a good purpose: left to themselves, however, they do more harm than good. Another efficient filtering material is common cotton, especially after chemical treatment with alkalies and acids. This is well known to those who are in the habit of collecting, for microscopic examination, the minute organisms which inhabit fresh waters—the diatoms, desmids, and other small algæ. A bag of stout, finely woven cotton cloth, or of the so-called "cotton-flannel," primitive and uncouth as it may appear, makes a very good tap-filter where the pressure of the water is not too great. It may be often renewed at a trifling expense, and in summer the odor of the entangled vegetable matter will probably call attention to it, and lead to its frequent washing or renewal.

FIG. 26.

All ordinary tap-filters are open to several fundamental objections, as may be illustrated by Fig. 26. In the first place, all those that contain an inside box to hold the filtering material are liable to allow some water to pass around the box and out of the filter without coming in contact with the filtering material at all. In the particular filter shown in the illustration, an attempt is made to prevent this by leather washers. In the second place, the success of such a filter in the accomplishment of its legitimate work depends upon the frequency with which it is cleaned. No filter can be self-cleaning. Attention on the part of some individual is necessary, and in the household, where such matters are generally left to the care or neglect of servants, the filters are more likely to be neglected than to be cared for. In many cases a filter once screwed upon the faucet remains for month after month without being cleansed, and is thus worse than useless. In the third place, if the filter is so arranged as to be readily removed for cleaning, the chances are that it will leak where it is attached, or, if it is attached so tightly as not to leak, the chances are that it will be difficult to remove, and thus fail to be cleaned. Moreover, with a filter of this kind the flow of water is more or less obstructed; and if the arrangement is such as to facilitate removal for cleaning, the temptation is always before the servant to remove the filter altogether in order to obtain the water more freely.

It is proper to say in this connection that, in case the water is delivered by service-pipes from a general supply, it is not necessary that the filtration should take place at the faucet, for most of the materials used for filtration and mentioned below can be obtained arranged in filters of large size intended for insertion in the house service. Of course, the objection to this arrangement is the expense, and the liability that when the filter has been once inserted it will be dismissed from mind, and proper care will not be taken to maintain it in efficient condition.

We come now to the larger forms of filters, to those which are portable, but which are intended to occupy a permanent position in the room, or in some cases to be placed in the tank from which the supply is drawn. The material which, next to simple sand, has probably been used as long as anything for the purpose, is stone. Some varieties of sandstone are particularly porous, sufficiently so to allow of the use of slabs of the stone as filters: other similar substances, such as pumice-stone or unglazed earthenware, have been employed; the most common arrangement being to insert the stone as a horizontal partition in a small tank or vessel. Here we have to deal, in the main, with simple mechanical action. The material should not be too porous. There is, at least, one variety of artificial stone in the market which is so porous that it offers almost no obstruction to the passage of water, and does not arrest anything but the grosser particles of solid substances. In any case these porous slabs are rather difficult to clean, as the intercepted particles penetrate to a considerable depth, and are not easily detached.

As filters of this second class are not restricted in size to such small dimensions, it is here possible to employ materials which shall perform something more than a mere mechanical action. Of such materials the best known, and, on the whole, the most efficient, is animal charcoal. All varieties of carbon formed by the destructive distillation of vegetable or animal matter possess the property of removing organic matter from solution, but to a very different extent. That prepared by the distillation of wood, *i. e.*, ordinary charcoal, possesses the property in too slight a degree to be of any service in the construction of filters; but animal charcoal, prepared from bones by distilling them in closed retorts at a rather high temperature, is one of the most efficient substances in this regard that we possess. One of the familiar uses to which animal charcoal is put in the industrial arts is in the refining of sugar, where it is employed to remove the coloring matter from the crude sirups.

There are many forms of filter in which animal charcoal is employed. One such filter, which is constructed according to the best principles, is shown, in section and in elevation, in Figs. 27 and 28. This is an English filter, manufactured by the London and General Water Purifying Company. The earthenware filter-box is filled with animal charcoal, in the form of charred bones, broken into small pieces, and freed from dust. The water is caused to pass *upward* through the filter, in order that matters spontaneously settling down may not be deposited upon the filtering material, and help to clog its pores, but may fall away from it and deposit elsewhere; the consequence of this is, that the filtering material requires less frequent cleansing. When cleansing does become necessary, the charcoal can be readily removed and renewed. This filter may be taken as a type of the better class of those which contain the charcoal in fragments rather than compressed into blocks. It will be noticed that there is no chamber for storing the filtered water; the water is filtered at the time it is drawn off for use, and when the filter is arranged as shown in Fig. 29, the water can be iced before filtration.

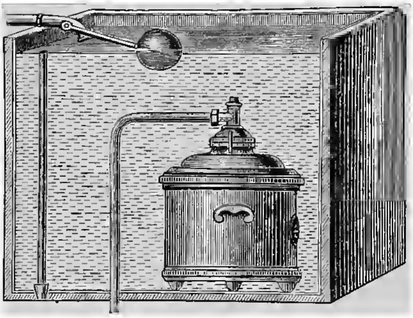

FIG. 27.

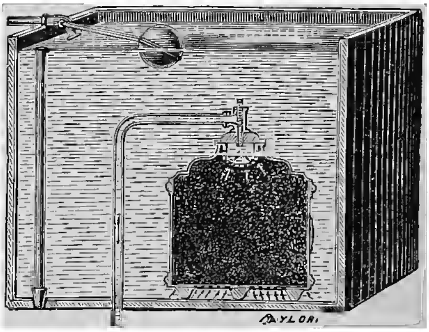

FIG. 28.

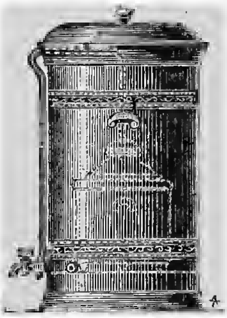

FIG. 29.

A great many experiments have been made with a great variety of waters, and by many observers, to determine the effect of filtration through bone coal, and there is no question that this material is able to remove a considerable proportion of the organic matter dissolved in a water, and thus to serve, not as a mechanical filter, but as an actual purifying agent. Frankland at one time proposed to filter the whole water-supply of London by this method. Although this would be expensive, it is not altogether impracticable. In large works it would be possible to wash and re-burn the coal from time to time, and the dust could be used in the manufacture of a fertilizer. The process would, however, undoubtedly be very expensive.

For some forms of filters, the bone coal is compressed into blocks, instead of being used in fragments; but, as a rule, for filters of small size, the latter method is to be preferred. The so-called "silicated carbon" is also presented in the form of blocks, and consists of the residue of the distillation of a variety of bituminous shale. Thus it is a coke mixed with mineral matter. In the common form of household filters of this make the block is cemented as a partition into an earthen jar, and is not readily cleaned. The material is, however, quite efficient as a chemical filter, and the difficulty of clogging is obviated in the tank-filters by allowing the water to pass first through sand, which removes the bulk of the suspended matters.

Another material, which has lately come into use to a considerable extent in England, is what is known as "spongy iron." It was observed a long time ago that metallic iron possessed the property of removing considerable quantities of organic matter from solutions containing it; and iron in turnings, and in other forms, has been proposed and used to a very limited extent as a means of purifying water. The material at present alluded to, and which forms the essential part of Bischof's Patent Spongy Iron Filter, is an iron which has been reduced from a hematite ore without fusion, and is consequently in a porous and finely-divided condition.

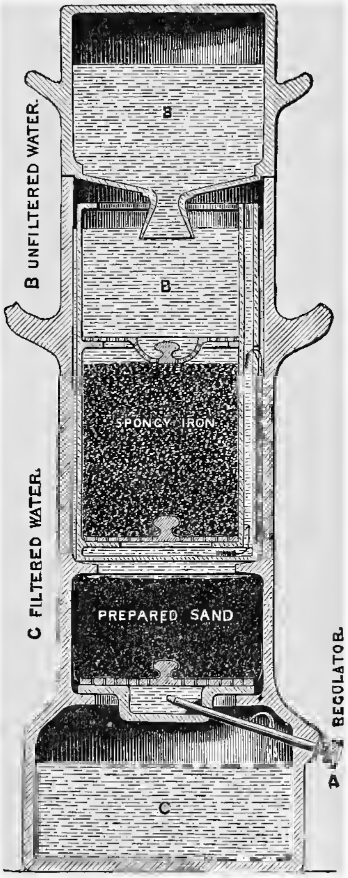

Fig. 30.—Spongy iron filter.

Fig. 30 represents one form of filter where the water is supplied from an inverted bottle, which must be refilled as often as empty. In other forms the reservoir of unfiltered water is kept full by being connected with the service-pipe by means of a ball-cock attachment. The material of all the vessels is earthenware.

The spongy iron is also employed on a larger scale in tank-filters.

There is no doubt that spongy iron is very efficient in destroying or at least removing a considerable proportion of the dissolved organic matter which occurs in natural waters,[1] but the filters are open to several objections. First, there is some difficulty in obtaining the filtered water free from iron. The filters are constructed with a view to the removal of the iron by the subsequent passage of the water through fragments of flint and quartz sand, with which has been mixed pyrolusite, the native oxide of manganese. But in spite of this, the filtered water does contain iron. Moreover, the construction of the portable filters is not such as would meet with favor in American households. A filter, such as shown in Fig. 30, which is 2¼ feet in height and 8 inches in diameter at the bottom, costs about $7.50, and delivers only nine gallons in twenty-four hours. If the filtered water reservoir were empty, it would take three-quarters of an hour to draw a quart of filtered water. Even with the large sizes the filtration is very slow. Thus a larger size, which costs about $26, filters only sixty-four gallons per day, that is at the rate of about a quart in five minutes.

On the whole, there is no better substance for ordinary household filters than animal charcoal. The charcoal should be renewed from time to time; how often, will depend upon the character of the water and the amount passed through the filter. If the coal be in blocks, the clogging of the pores will indicate the necessity for cleaning; if in granules (which on many accounts is preferable), it may be well to renew the charcoal once in six or twelve months, according to the amount of water used. In the case of a filter fixed with some permanence, it is worth while to have made a simple chemical examination, if there is reason to suspect the efficiency of the filter: this will indicate whether the work is still being properly performed. It is true in the case of these, as of filters in general, that unless attention is paid to them, and they are cleaned at proper intervals, their presence is worse than useless.

We come now to the discussion of filters suitable for large tanks or cisterns. Most of the materials in common use as filters can be obtained in forms suitable for insertion in ordinary tanks or cisterns, from which the filtered water can be delivered by gravity, but cisterns for the storage of rain-water are more commonly built underground or in the cellar of the house. A common method for filtering the water from such cisterns is to construct a partition of porous bricks, setting off a portion of the cistern as a pump-well into which the water can enter only by passing through the bricks. One form of construction is represented in the accompanying cut taken from *Scribner's Monthly Magazine* for September, 1877.

When the brick partition is new, it is undoubtedly of good service;

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[1] I am aware of recent German experiments which tend to discredit the value of spongy iron as a purifying medium (Dr. L. Lewin, Zeitschrift für Biologie, XIV. [1878], p. 504). These experiments, it seems to me, were unfair to the filter, which was expected to perform that which it never claimed to do. On the other hand, there is very likely in England, on the part of the inventor and others, a tendency to overrate the value of the material.

but it soon becomes clogged, and covered on the outside with a deposit of organic matter, so that after a time the water which passes through the brick wall must first have an opportunity to leach out what it can from this mass of decaying matter. Fortunately in many cases this clogging so interferes with the passage of water through the wall, that attention is called to the fact, the cistern is cleaned, and the filtering wall is cleaned or renewed; but where the filtering surface is large, and the filtered-water chamber of considerable size, the water may be in many cases supplied in sufficient amount long after the process of filtration is an injury rather than a benefit. Some of the deposit taken from the surface of such a filtering-wall recently came under the observation of the writer. It contained a considerable amount of animal matter in the remains of various insects, worms, etc. Chemical examination showed that it contained 19.8 per cent. of organic matter (*i. e.*, loss on ignition), and this organic matter was very nitrogenous; in fact, the organic nitrogen amounted to 1.11 per cent. of the whole mass.

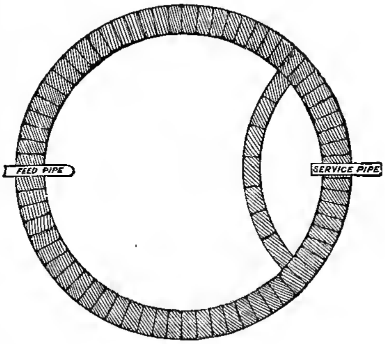

FIG. 31.

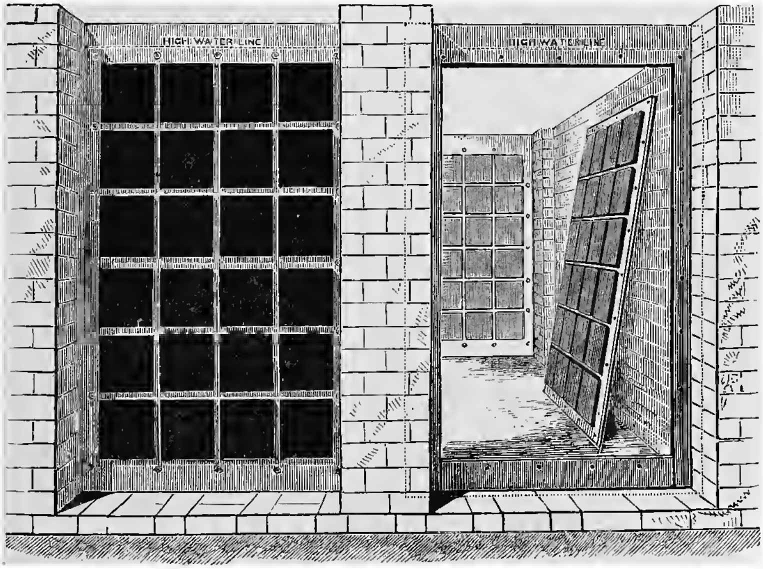

FIG. 32.

The objection made to the arrangement which has been described is not to the material; for porous brick is efficient in removing suspended matters from water passed through it, and communicates nothing that can be or can become injurious. The trouble lies in the fact that the wall soon becomes clogged, and as a rule is not readily accessible. Moreover, when the cistern furnishes the whole or a large part of the household supply, it is impossible to renew the filtering wall frequently, or even to thoroughly clean the outer surface. The best that can be done under ordinary circumstances is to clean the outer surface of the wall as thoroughly as may be with a stiff brush every few months, and to renew the wall whenever the probability of a rainy season allows.

The filtration in the cistern may, however, be better accomplished in other ways, two of which will be indicated. First, to take the place of the wall, the filtering material may be arranged in a frame capable of sliding in a groove and of being readily lifted from its place. The filtering material may consist of porous tiles or of blocks of animal charcoal; and, if duplicate frames are provided, the grooves may be so arranged that a fresh frame can be lowered into place before the old one is taken away. Fig. 32[1] represents a cistern constructed with such frames containing blocks of animal charcoal as prepared by Atkins & Co., London. These blocks can be readily cleaned by scraping the outer surface (at some expense, to be sure, of the material of the blocks), and they can be renewed when necessary. They are made of various densities; the most dense permitting the passage of 30 to 40 gallons per square foot per day, while the most porous pass from 250 to 300 gallons. For use in ordinary cisterns tolerably porous blocks would probably answer well enough, and for such use as this the charcoal is more conveniently employed in this form of blocks than as fragments.

The arrangement which has been described is rather expensive for common use; although, if the necessary provision were made in the original plan for the construction of the cistern, it would, on the whole, be more satisfactory than other plans which involve less outlay at the start. Various other methods are in use for employing animal charcoal in cisterns, one of which is represented in the woodcut (Fig. 33).[2]

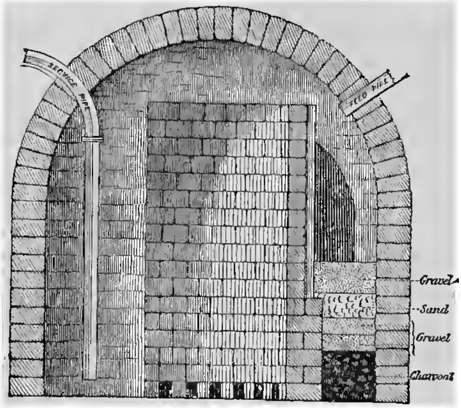

FIG. 33.

This arrangement is open to the common objection that the difficulty of access throws an obstacle in the way of the renewal of the material as frequently as necessary. A better plan on

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[1] Taken by permission from Fanning's Water-Supply Engineering.

[2] This cut is taken from Scribner's Magazine. The writer there speaks of using wood charcoal: animal charcoal would be more effective.

many accounts is represented in Figs. 34 and 35. Here the box, which contains the sand and charcoal, is coupled on to the suction-pipe of the pump. The box can be removed from time to time, say once a year at least, and the contents renewed. These figures are taken from Bailey Denton's "Sanitary Engineering." The same object may be accomplished by other devices, among which are several which rest on the use of the compressed blocks similar to those spoken of above.

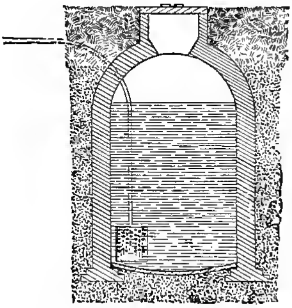

FIG. 34.

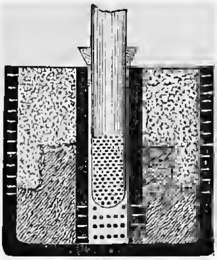

FIG. 35.

On the Softening of Hard Water.

The disadvantage of hard water for domestic use has already been referred to. Hardness is not peculiar to water from any one source; rivers and lakes, springs and wells, are all liable to furnish hard water when they are situated in regions which contain deposits of limestone or of gypsum or of magnesian minerals. To understand the processes employed for softening hard water, it is necessary to understand the cause of the property which we designate as hardness.

There are many mineral compounds which, if present in water, give to it this property, and thus render it unfit for domestic use. The most commonly occurring of these substances are the carbonate of lime and the carbonate of magnesia, the sulphate of lime and the sulphate of magnesia. We will first consider the effect of the carbonates, and in what follows nearly all that is said about carbonate of lime will apply also to carbonate of magnesia. Neither carbonate of lime nor carbonate of magnesia is dissolved by pure water to any considerable extent; if, however, the water be charged with carbonic-acid gas its solvent power is very much increased and a considerable quantity of the carbonates will go into solution. This is generally explained by supposing that there is actual chemical combination between the carbonic acid and the carbonate of lime, forming what is called a *bicarbonate.* Since meteoric water, in its passage through the air and ground, always absorbs carbonic acid, and since carbonate of lime is widely diffused as limestone, marble, chalk, etc., it is not surprising that many natural waters are hard on account of the dissolved bicarbonate of lime. Such water may be softened in several ways. If common soap be added to the water, the water seems to curdle, but refuses to form a froth or "suds" until, by the mutual action of soap and bicarbonate of lime on each other, the lime is nearly all converted into an insoluble lime-soap which forms the curd alluded to. After this point is reached, any additional soap becomes available for washing, but this method of softening is an expensive one. Another method, often employed in the household, consists in adding ordinary carbonate of soda (washing soda, soda crystals) to the water. The chemical effect of adding carbonate of soda to the bicarbonate of lime is to form bicarbonate of soda, which is soluble in water, and carbonate of lime, which is practically insoluble, and which, by this means, is removed to a large extent from the water and settles as a fine powder if the water is allowed to stand. A simpler method than either of the two foregoing consists in boiling the water for half an hour or more. The boiling causes the expulsion as gas of the carbonic acid, the presence of which enabled the water to dissolve the carbonate of lime; when this carbonic acid is driven off, the carbonate of lime remaining settles out as a fine white powder. The deposit which settles from the boiling water adheres more or less to the bottom and sides of the vessel in which it is boiled, and often causes serious trouble in steam-boilers.

None of the three methods just mentioned is practicable on the large scale. It is possible, however, to soften such water even on the scale necessary when dealing with a general water-supply. The method employed was invented and patented, about the year 1844, by Thomas Clark, professor of chemistry in the University of Aberdeen; but the patent has now expired. The process is a strictly chemical one, and may be explained as follows: If we take 56 pounds of pure quicklime, and expose it to moist carbonic acid, it will absorb 44 pounds of carbonic acid, and unite chemically with it. After the chemical union, we shall have as a result 100 pounds of carbonate of lime. As already said, this carbonate of lime will not dissolve of itself to any extent in water; but in the presence of carbonic acid there is formed soluble bicarbonate of lime; and the amount of carbonic acid necessary to convert 100 pounds of carbonate of lime into bicarbonate is 44 pounds, or *an amount exactly equal to that which is already combined in the* 100 *pounds of carbonate.* Suppose that we have proceeded in this way, and have our 144 pounds of bicarbonate of lime dissolved in water. If now we slake 56 pounds of quicklime, and add to the solution, this will combine with the 44 pounds of *extra* carbonic acid, and form 100 pounds of carbonate of lime, in addition to the original 100 pounds, which, being now robbed of the carbonic acid which kept it in solution, will separate out from the solution as a white powder along with the newly formed carbonate of lime. It is to be said that carbonate of lime is not absolutely insoluble in water, and after the softening a small amount remains in the softened water, not enough, however, to be objectionable.

In the case of any given water, the amount of lime necessary may be determined by analysis; or it may be run in until it is evident from certain simple chemical tests that enough has been added. The lime is employed as lime-water, or, rather, milk of lime. After the treatment, the water is allowed to subside for from 12 to 24 hours, and drawn off from the sediment. The readiness with which the finely divided carbonate of lime settles depends somewhat upon the character of the water; and, as it settles, it drags down with it and removes from the water a not inconsiderable proportion of the organic matter present; if the water is colored by peaty matter, a very appreciable decolorization is effected. Experience, however, would seem to show that the process gives the best results with water which is naturally clear, such as spring water; and, in the case of turbid river waters, the softening process should be followed by filtration.

Whether the process has been employed to any extent in this country the writer is not able to say. It has been used in England in some localities where it was necessary to soften as much as 1,000,000 gallons of water daily, and it could be employed for larger quantities. As is the case with other similar operations conducted on the large scale, a very important question is how to dispose of the sediment or sludge. This sediment, if the water is tolerably pure, is white, and when dried can be sold as whiting or for any use to which powdered chalk or marble is put. A portion could be dried and burned into lime, and thus be used over again in softening additional quantities of water; but there would always be a great deal to dispose of, because, in addition to the carbonate of lime formed from the lime employed, an equal quantity is taken from the water which is softened.

The expense of the process depends upon the facilities for disposing of the whiting produced. In some localities it would be readily disposed of and pay a large proportion of the expense of softening the water; in other localities it would probably beg for a market. The process, however, is one which deserves a much wider application than has yet been made of it. It should be said that the hardness caused by the presence of bicarbonate of lime (or magnesia) is called "temporary" hardness, because it may be removed by boiling. Some waters are said to have "permanent" hardness; they are not softened by boiling or by Clark's process, and the hardness is generally due to the presence of sulphate of lime (gypsum), although the sulphate and other soluble compounds of magnesia have the same effect. There is no economical process which is practicable on the large scale for softening such waters, and a water which has a high permanent hardness is unsuited for general use. On the small scale such water may be softened by carbonate of soda, which acts upon the soluble sulphate of lime, converting it into carbonate of lime, which, as we have already seen, is nearly insoluble in water. The effect of such a hard water upon soap is the same as that of a water, the hardness of which is due to the presence of bicarbonate of lime, but there is a considerable difference in the character of the deposit or incrustation which is formed in steam-boilers. The sulphate of lime, although somewhat soluble in cold water, deposits because it is almost completely insoluble in water having a temperature of about 130° C., a temperature which is reached when the pressure of steam in the boiler is that of 2½ atmospheres. It forms a scale which is very coherent and difficult to detach, while the carbonate of lime, in the absence of other deposits, generally settles as a loose sludge, which, however, under some circumstances, becomes tolerably compact. A particular discussion of boiler incrustation and of the equally important boiler corrosion hardly comes within the scope of the present treatise.

Chemical Treatment.

The chemical treatment of water, in order to make it potable, is seldom undertaken on the large scale, except so far as to remove the carbonate of lime by Clark's process, just described. On the small scale and under peculiar circumstances, such as in an army on the march or in an enemy's country, where good water cannot be had, chemical processes may be and have been carried out. Distillation is practised on shipboard and in a few unfavorable localities on land. Treatment with permanganate of potash (or permanganate of potassium), which can now be bought quite pure in the crystallized condition, serves a good purpose as far as it goes. It acts readily upon organic matter in a certain stage of decay, and destroys sulphuretted hydrogen and other offensive gases. Some organic substances, however, are not affected by it, and there is no security that a dangerous water can be made safe by its use. The permanganate of potash, which is itself highly colored, is applied in solution, and it is added in successive portions in quantity sufficient to impart a faint pink color to the water, a tint which remains permanent for five or ten minutes. By the decomposition of the permanganate there is formed finely divided oxide of manganese, which may be removed by filtration, although it is probably not injurious, at least in the quantity in which it would thus be taken.

Alum is used very frequently with turbid waters. In many cases the action depends upon the presence of carbonate of lime, which, with the alum, forms sulphate of lime and a hydrate of alumina, while carbonic acid is set free. The hydrate of alumina settles and carries with it the suspended matter. In the absence of carbonate of lime, a little calcium chloride and carbonate of soda may be added to the water after the alum has been added.

Perchloride of iron acts in the same manner as alum, and it has been proposed to apply the method on the large scale, adding first the perchloride of iron and then carbonate of soda. In this case the precipitate is hydrate of iron (ferric hydrate), and it drags down with it the fine suspended matter as well as a small quantity of the dissolved organic substances.

The most common and the most simple method of treating an impure water, in order to make it wholesome, is to boil it. Volatile gases are driven off by this operation, and the organic matter is somewhat changed in character. It would seem that in some cases dangerous germs (if there are such) are killed; at any rate it has been proved beyond question that some particular waters cause sickness when drunk directly, but produce no disagreeable effect when drunk after being boiled. The effect seems to be more satisfactory if tea-leaves or other somewhat astringent vegetable matters are boiled with the water.

On the Effect of Conduits and Distribution Pipes upon Potable Water.

Most of the questions arising with reference to the conveying of water in conduits, and its distribution by mains and service-pipes, are of an engineering character. There are a few points, however, of sanitary importance. As far as masonry conduits or aqueducts are concerned little is to be said ; such conduits should be, and generally are, covered, as a means of protecting the water from accidental defilement. The water has some action on the mortar or cement to which it is exposed and becomes appreciably harder ; this is especially the case while the masonry is new.

The material most commonly employed for the main distribution pipes is cast-iron. Cast-iron is readily acted upon and caused to rust by most waters, and the water, by exposure to the iron, acquires more or less of a rusty character. The presence of what little iron is actually dissolved is of no significance, and the suspended particles of iron rust can hardly be regarded as deleterious to health. The water is, however, sometimes rendered unfit for washing, and becomes objectionable in appearance. The action on the pipes is so great, especially when soft waters are conveyed through them, that they are seldom used now except the surface be protected in some way from corrosion. The process commonly employed is that devised by Dr. R. Angus Smith : the newly cast pipes, which must be free from rust, are heated to a temperature of some 500° Fahr., and then dipped, perpendicularly, into a hot bath of coal-tar pitch mixed with a small proportion of heavy coal oil. In this bath they are allowed to remain for a short time and then withdrawn. The firmly coherent coating thus formed does not afford absolute protection against rust, but it has proved very efficient in practice. Of course, from a sanitary point of view, this surface is as good a one as could be desired.

It has more recently been proposed by Professor Barff, of London, to protect articles of iron, among other things water-pipes, from corrosion, by covering them with an artificial coating of the black oxide of iron. The coating is produced by exposing the metal to superheated steam at a high temperature, and when once formed it protects the iron from atmospheric and other agencies which would corrode it. If the process proves practicable as far as expense goes, it will, no doubt, be of great use, especially in protecting iron service-pipes.

The way in which the pipes are connected together is not without influence on the water transmitted through them. Cast-iron pipes are now usually connected by means of what is called the hub and spigot joint, one form of which is shown in Fig. 36. The joints are usually first packed with tow or jute, and then melted lead is run in and driven up with a set.

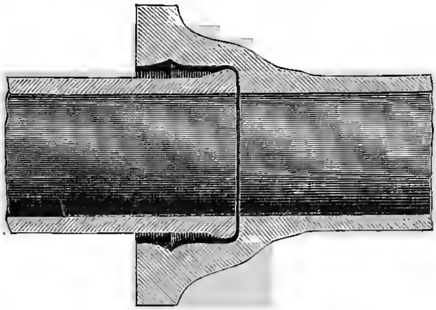

FIG. 36.

In the case of long mains the tow may, for a considerable time after the pipe is laid, impart an unpleasant taste to the water which passes through. Trouble has been experienced in England on this account, and the Rivers Pollution Commission recommend that, in the case of all mains of sufficient size, the joints should be carefully pointed up with Portland cement from the inside, so that the water cannot come into contact with the tow-packing. This action will, perhaps, explain in part the fact of the deterioration of water in "dead-ends," which is usually ascribed to the stagnation of the water.

In this country, wrought-iron pipes, coated within and without with cement, are used in many places, and at times such pipes can be laid much more cheaply than cast-iron pipes. There is some question as to their durability, but most of the apparent failures are due to imperfections in the original work, especially in applying the cement, or in mixing the cement with sand—a practice which seems to be unwise.[1]

The pipes are made of sheet-iron, with the edges rolled together and riveted, as shown in section in Fig. 37. By the use of a longitudinal rib, as shown in Fig. 38, or by other devices, the pipe may be made water-tight, even under a very considerable pressure. Where the lengths of pipe come together, the joint is usually covered with a wrought-iron sleeve filled in with cement, as shown in Fig. 39. Sometimes, however, the ends of the pipes are shaped in such a manner that the lengths can be telescoped together so as to form a lap of several inches. However arranged, the result is a continuous coating of cement within the pipe, and the effect

FIG. 37.

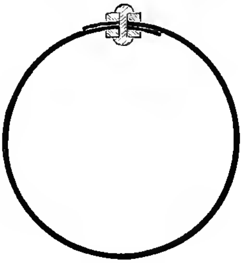

FIG. 38.

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[1] See a discussion of this subject in the Report of the Board of Water Commissioners of the City of Springfield, Mass., 1876.

upon the water is such as has been described in the case of aqueducts of masonry.

The service-pipes, by which the water is conveyed from the street mains to the houses, are most frequently made of lead. On account of the known poisonous character of the soluble compounds of lead, the question of the propriety of such use has often arisen, and has been often discussed. It is true that all natural water acts upon bright lead to a greater or less extent, but in the case of most potable waters the action on the pipes soon becomes almost imperceptible. This decrease in the rapidity of the action is due to the formation, in the interior of the pipes, of a protecting coating of various insoluble compounds of lead. Although for many years lead pipes have been almost universally used in city distribution, cases of lead-poisoning from this cause are of very rare occurrence. The water of Lake Cochituate, as supplied in Boston, Mass., through lead pipes, always contains traces of lead in solution, but it is said that there is no well-authenticated case of lead-poisoning from the use of this water.[1] Analysis has shown that the amount of lead taken up by the water in passing through some 150 feet of pipe, which has been in use for some years, is only 0.03 parts in 100,000, or less than 0.02 grain in the U. S. gallon. Water which is allowed to remain in the pipe for some time, or is drawn from the hot-water faucets, may contain as much as 0.1, or even 0.2 part in 100,000 (from 0.06 to 0.12 grain in the gallon), and wherever lead distribution pipes are in use it is safer always to run to waste enough water to clear the pipes, and never to use, for drinking or for cooking, water which has passed through the pipes while hot. The amount of lead necessary to produce injurious effects cannot be stated, as there is very great difference in the susceptibility to lead-poisoning; some authorities hold as little as one-fortieth of a grain in the gallon to be unsafe, although few persons would be sensibly affected by this amount. The Croton water supplied to New York City is similar to the Boston water in its action on lead,[2] although at least one case of poisoning has been reported, which was supposed to be due to the daily use for some time of water which had stood over night in the pipes.

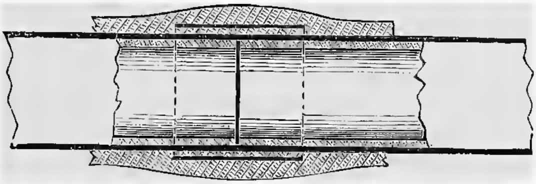

FIG. 39.

The water of many wells acts violently on lead, so that it may be stated, as a general rule, that lead pipes should not be used for conveying well-

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[1] See Report of the Mass. State Board of Health, 1871.

[2] See Report of the Metropolitan Board of Health, New York, 1869, p. 420.

water. Moreover, a portion of any suction-pipe drawing water from a well is exposed to the alternate action of air and water, and such circumstances are very favorable for corrosion.

Other materials besides lead have been and are used for service-pipes. Block tin is perhaps as good as any, from a sanitary point of view; but when laid in moist ground it is rather rapidly corroded; it is, moreover, somewhat expensive. The tin-lined lead-pipe affords most of the advantages possessed by the block-tin: it is important that the tin used in its manufacture be pure, and that the connections be made in such a way as not to expose any lead to the action of the water. Since in the ordinary process of connecting the pipes there is liability of exposing the surface of lead, peculiar couplings have been devised, but they are by no means generally employed.

Various sorts of "enamelled" wrought-iron pipes are in the market. The coating or enamel is generally some preparation of coal tar, with or without linseed oil, and, where it is properly applied, it is quite durable, and protects the iron from the action of water. This sort of pipe is particularly adapted for use in wells, where a portion of the outer surface is exposed alternately to the action of air and water.

Zinced or "galvanized" iron, as it is called, is often used as a material for water-pipes. It is prepared by dipping the iron, previously well cleaned by means of dilute acid, into a bath of melted zinc. The zinc adheres firmly to the surface of the iron, and penetrates it to a certain extent, so that we do not deal with a simple coating, such as we have on tinned iron, or on the various forms of enamelled pipe. When the zinced iron is exposed to the action of water, corrosion begins at once, and goes on with greater or less rapidity. At first the action is on the zinc alone, provided the original iron was free from rust, and the treatment with zinc was thorough; but after a time the zinc which remains will cease to protect the iron, and iron rust will begin to form. As regards this action, it is simply a question of time. Water that has passed through zinced pipes will be found almost always, if not invariably, to contain zinc compounds, either in solution or in suspension; the amount, however, is so small that it is not to be regarded as deleterious to health.[1]

Impure Ice.

In connection with a discussion of matters relating to water-supply, something should be said about impure ice. Ice is used to an enormous extent in many parts of the United States. Where the water is taken from running streams or from ponds, or is stored in uncovered reservoirs, it becomes in summer very warm. In fact, even in the Northern States the water is sometimes so warm as to require an equal weight of ice in order to make it cold enough to drink. It is very important that the ice should be of good quality. It is well known that water in freez-

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[1] For a full discussion of this subject, see Dr. Boardman's paper in the Report of the Mass. State Board of Health for 1874.

ing excludes foreign substances, and that ice is always purer than the water on which it forms; on this account there is really little cause to suspect contamination of the ice when it is cut in moderately deep ponds. It sometimes happens that the minute algæ, which were spoken of on page 237, float up to the top of the pond in winter, and are frozen into the ice. This may make the ice unmarketable on account of its appearance; that it is injurious to health is doubtful; but if the algæ are in the ice, the water should be filtered when used.

There have been cases of sickness which have been attributed to the use of impure ice, but in such cases the ice has been cut from stagnant pools unfit for the purpose. In the summer of 1875, at Rye Beach, a sea-shore watering place in the State of New Hampshire, there was an outbreak of sickness among the guests of one of the large hotels, which was ascribed by the attending physician to the ice which was used. The sickness was described as "a disturbance of the digestive system, characterized by a sensation of giddiness and nausea, vomiting, diarrhœa, severe abdominal pain, all of which was accompanied by fever, loss of appetite, continued indigestion, and mental depression." After the ice was suspected as the cause, it was found that it had been cut from a small stagnant pond situated near the sea, until within a short time connected with the ocean, and into which a small brook entered, bringing a quantity of sawdust from several saw-mills. The pond contained a large amount of decomposing matter, and the gases arising from it in summer were very offensive.

A portion of the ice was carefully melted, and was found to contain considerable decaying vegetable matter in suspension. A chemical examination was made, with the following results, which are, for comparison, placed by the side of the results obtained from the examination of ice of good quality:[1]

RESULTS EXPRESSED IN PARTS IN 100,000.

	Rye Beach Ice.		Boston Ice.
	Unfiltered.	Filtered.	Unfiltered.
Ammonia	0.0208	0.0213	0.0045
Albuminoid ammonia	0.0704	0.0165	0.0050
Inorganic matter	7.80	6.88	0.45
Organic and volatile matter	5.72	2.84	0.31
Total solids at 212° Fahr.	13.52	9.72	0.76
Chlorine		3.23	0.02

It thus appears that ice cut upon a very foul pond was itself foul, although, of course, the ice-water was not as bad as the pond-water. A

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[1] See a paper by A. H. Nichols, M.D., in the Seventh Report of the Mass. State Board of Health, 1876, p. 465.

sample of the latter was examined in the summer of 1875, taken under as favorable conditions as possible, with the following results:

Ammonia	0.0197	in 100,000 parts.
Albuminoid ammonia	0.0597	"
Chlorine	34.00	"
Total dissolved solids	72.96	"

These results should be compared with the filtered ice-water above, and it will be evident that the water in freezing rejects some foreign substances. This is not, however, a purifying action, but amounts practically to diluting the objectionable matter or bringing a smaller amount at one time into the system. On this account, safety demands that ice should not be cut for domestic use on ponds or streams which are so polluted as to be rejected for water-supply.

The question with artificial ice is somewhat different from that which has been discussed, because, in the manufacture of artificial ice, the water is frozen solid, and whatever substances are dissolved in the water remain in the ice. Therefore, for the manufacture of artificial ice, it is particularly important that unobjectionable water should be employed.

THE SANITARY EXAMINATION OF WATER.

Occasion for the sanitary examination of water arises in two ways. In the first place, it may be a question of introducing a new system of water-supply, or of extending a system already existing by connecting additional sources. In the second place, it may be a question whether a water already in use is contaminated, or is in danger of becoming so.

In either case, an important aid in the sanitary examination is offered by chemical analysis, although it happens comparatively seldom that chemistry alone is sufficient to decide absolutely, as will appear from what follows. In discussing the chemical examination of water, we shall consider—first, in a general way, the analytical methods which are in common use, and afterwards the interpretation of the results of the analysis according to the various methods employed and in connection with the examination of different classes of waters.

In considering the various methods employed in water analysis, we may classify the substances occurring in a natural water according to the following scheme:

1. Suspended matter......
   - Inorganic.
   - Organic
     - Animal.
     - Vegetable.
2. Dissolved matter.......
   - Gaseous.
   - Solid
     - Inorganic.
     - Organic
       - Animal.
       - Vegetable.

Suspended matter.—The determination of the suspended matter is quite simple. A paper-filter is dried at 100° C., and weighed. A measured quantity of the water is then passed through it, and the filter with its contents is dried at the same temperature as before, and again weighed. The difference in weight is the weight of the total suspended matter. The filter is then burned in a platinum crucible, and the residue is rather strongly heated; the weight of what remains, minus the weight of the ash which the filter is known to leave, gives the weight of the inorganic matter in suspension.

Another method, which is quite commonly employed, consists in evaporating equal quantities of the water before and after filtration. The difference in the weight of the residues when dried at the same temperature may be regarded as representing approximately the amount of matter in suspension. Of course, in this way, all the error of the determination falls upon the suspended matter. Moreover, it is difficult to take two specimens of water at the same time which shall contain the same amount of suspended matter, so that no very great accuracy in its determination is required, and the estimation is principally valuable with reference to the question of filtration.

When we come to express in figures the results of this and of other analytical determinations, we find that, unfortunately, there is considerable diversity of practice. The following are the principal modes of expression:

(1) In grains to the English (imperial) gallon, which measures 277 cubic inches and is equivalent to 10 lbs. or 70,000 grains of pure water. This method is still quite common in England.

(2) In grains to the U. S. gallon, which measures 231 cubic inches and is equivalent to 58,372 + grains of pure water. This method is very common in the United States.

(3) On a decimal basis, either as so many parts in 100,000 or in 1,000,000, or as so many milligrammes in a litre, which is the same thing as parts in a million. This method is common in France and in Germany, and is coming into use very extensively in England and in this country.

Besides these methods, there are others used by individual authors, or to a limited extent. Thus, in at least one work on mineral waters the saline constituents are expressed in *grains to the pint*, and at least one analyst states his results as so many pounds in a million U. S. gallons. This last method is not without reason, and is certainly better than employing grains to the gallon, because the amount of water used or required is usually estimated in millions of gallons and a pound conveys a definite idea to most minds, while a grain is a quantity of which most persons have no conception. It would, however, be better if it could be agreed to use the "parts in 100,000." Any one can understand this method, for we mean that there are so many pounds of such and such material in 100,000 pounds of water, or so many grains of the material in 100,000 grains of water, or any other unit may be used and the proportion remains the same.

Microscopical examination.—The nature of the matter which a water carries in suspension is best learned by microscopical examination; this is especially true of the organic matter. Starch-grains, hair of human beings or of domestic animals, epithelial scales, muscular fibre, wool, linen, cotton—these are substances which may be recognized without difficulty under the microscope, and are evidences of more or less serious contamination.

Almost all waters contain animal and plant life. Of animals, some are so large as to be recognized by the unaided eye; such are the *Daphnia pulex*, Fig. 40, A, the *Cyclops quadricornis*, Fig. 40, B, and other similar animals. These creatures, although one hesitates to drink them deliberately, are no evidence of impurity, and they do not themselves render a water unwholesome. They occur in almost all ponds and rivers, and some regard them even as a guarantee of purity. It is fair, however, to say that these animals secrete oil under their shells (carapaces), and some have ascribed disagreeable tastes in pond-waters to an abnormal amount of this oily matter. The evidence in favor of this explanation is not strong.

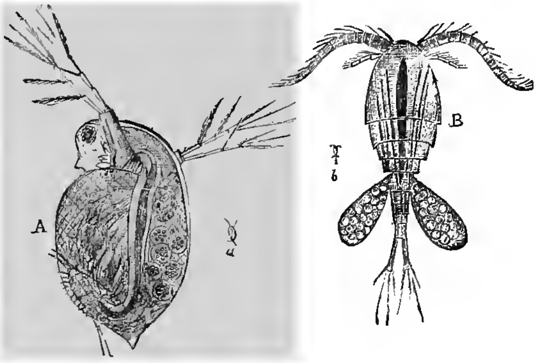

FIG. 40.

With regard to plants, something has already been said about certain sorts of algæ. (See pp. 235 and 238.) The algæ as a rule, including diatoms and desmids, are of little account unless they increase to a great extent and decay in the water. The fungi—plants destitute of green or other coloring matter and growing upon or in the presence of decaying organic substances—the infusoria, or at least some of the forms of life included under this head, the bacteria, vibrios, etc., must be looked upon with suspicion, as they are found in waters known to be impure.

Gaseous substances.—With occasional exceptions, no water which is likely to come under consideration as a source of domestic supply would contain other gases than those of the air—oxygen, nitrogen, and carbonic acid. These gases are present in very varying proportion in different waters. The waters of artesian wells and of springs generally contain little oxygen, often none at all; waters from highly polluted sources are also deficient in this gas; waters which have been freely exposed to the air, and which do not contain any considerable amount of decaying organic matter, are often charged with an excess of oxygen.[1] Nitrogen occurs in a certain amount in all waters, and in some mineral or effervescent waters it forms the largest, the main part of the dissolved gases. Carbonic acid is present in all potable waters, and its presence is of important influence in determining the amount of carbonate of lime which a given water contains, and the solvent effect of water on many minerals is due to the presence of carbonic acid.

It was formerly the general custom to make a complete quantitative analysis of the various gases present in a sample of water under examination. The analysis was made by boiling out the gases from a measured quantity of water and submitting the mixture obtained to the accurate but tedious methods of gas analysis. As, however, these determinations were almost never made on the spot, but, on the contrary, often on samples of water which had been standing for days or for weeks, they were nearly worthless, and are now rarely made except in the case of mineral waters.

There has lately been devised a method, known as Schützenberger's, for determining the amount of dissolved oxygen in water, a method which admits of being performed with sufficient accuracy out of doors. The following table contains the results obtained by this method on the River Seine by M. Gérardin, Inspecteur des établissements insalubres, Paris, in the summer and fall of 1874.[2]

Kilometres.		Oxygen.
	Corbeil (above Paris)	9.32
0	Pont de la Tournelle, Paris	8.05
8	Auteuil (below the city, but above outlets of main sewers)	5.99
31	Epinay (below all sewers)	1.05
78	Pont de Poissy	6.12
93	Pont de Meulan	8.17
109	Mantes	8.96
150	Vernon	10.40
242	Rouen	10.42

Each of the figures in the foregoing table is the mean of a number of determinations. The figures denote the number of cubic centimetres of oxygen in one litre (1,000 cubic centimetres) of water. The theory is that a water which is polluted by decaying organic matter not only calls upon the air about it to furnish oxygen for the combustion of the decaying matter, but uses up in the process more or less, sometimes all, of

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[1] According to Bunsen's tables (Bunsen: Gasometrische Methoden, Braunschweig, 1877), one litre of *pure water* at 0° C., and under the normal atmospheric pressure, will dissolve from the air 8.64 c.c. of oxygen; and at 20° C., 5.96 c.c. The solubility of this gas in natural water seems to be increased by the presence of foreign substances, and the excess of oxygen which has been found in some instances may be in part due to the evolution of the gas by growing plants.

[2] See Assainissement de la Seine, etc., deuxième partie, II. Annexes, p. 8.

the oxygen previously dissolved in the water. The amount of dissolved oxygen is thus considered by some to be an indication—in the inverse direction, of course—of the amount of impurity present.

Although this determination of dissolved oxygen is valuable in tracing the course of a polluted stream, it has little absolute value, for the ground-water generally and the water of unpolluted springs and of deep wells are deficient in oxygen.

Total solids.—The determination of the total dissolved matter is made by evaporating a measured quantity of the water to dryness in a platinum vessel, drying at some definite temperature, and weighing the residue. There is considerable diversity among chemists as to the quantity of water which should be evaporated and the temperature at which it is best to dry the residue. The determination is, of necessity, an inexact one, because the solid matter obtained does not exactly represent what was in solution. In the evaporation some substances pass off with the steam and are lost. Other substances are changed in character by the treatment. If the residue be dried at the temperature of boiling water, some of the salts retain their water of crystallization; at a somewhat higher temperature, even as low as 140° C., the organic substances begin to be decomposed and lose weight. In spite of this, some chemists use a temperature as high as 180° C.

For sanitary purposes it is not at all necessary that this determination should be very accurate, for it is a matter of no importance whether there are 3 or 6 parts, whether 17 or 20, of solid matter in 100,000 parts of the water. The more common custom is to dry the residue at the temperature of boiling water (100° C. or 212° Fahr.), and to consider what remains at that temperature as the "total solid residue." As already stated, the expression "total impurity" is sometimes used; but this term is open to objection, especially in the case of a water known to be pure, *i. e.*, unpolluted.

Mineral matter.—It is unnecessary, for sanitary purposes, to make a complete analysis of the mineral matter which a water holds in solution, or which is obtained by evaporating the water to dryness. A few substances are, however, determined for special reasons.

It is generally felt to be important to ascertain the amount of chlorine. This element does not exist free in the water, but in combination, forming chemical compounds which are known as chlorides. Unless present in excessive quantity, the chlorides which occur in natural waters are harmless; but it happens that chloride of sodium (common salt) is an invariable constituent or accompaniment of all excremental matter, and of all refuse from the household and from most manufacturing operations. It is true that salt exists in the air of all places not too far from the sea, and that chlorides are found in all natural waters. The amount, however, is very small, except quite near the sea and in the neighborhood of salt deposits. Thus, with certain restrictions, chlorides become evidences of contamination; and since chlorides are not absorbed to any extent by the soil, nor chemically changed by exposure to the air, they remain after other evidence of contamination has passed away. The extent of the pollution cannot, however, be estimated from the amount of chlorine present, because in various polluting fluids the amount of chlorine varies greatly. As an example we may take sewage itself. A number of experiments were made some years ago to ascertain the character of the sewage of Boston and Worcester. In one series of experiments made on the same Boston sewer, at different hours of the day and night, the chlorine was found to vary from 42 parts in 100,000 to 3.2 parts. The average of 33 day samples from this sewer was 18.94, and of 4 night samples was 4.50. The average of 52 samples of Worcester sewage was 3.6 in 100,000, while some of the Boston sewage from other sewers contained very much more than the maximum just given.[1]

It is customary to determine the amount of ammonia and of nitrogen which exists in the form of nitrites and nitrates, not because these compounds are likely to exist in quantity sufficient to work harm of themselves, but because they are the result of the decay or decomposition of nitrogenous organic matter. As a rule, the amount that occurs in unpolluted water is very small, and even in polluted waters it is small when expressed in figures. The ammonia can without difficulty be determined when present, even in minute quantity; the significance of the amount found will be discussed in connection with the interpretation of the results of the examination of different classes of waters.

The amount of nitrogen as nitrites and nitrates does not bear any direct ratio to the amount of organic matter originally present in the water, although these compounds are generally to be taken as indications of its previous existence, and in shallow wells are generally to be ascribed to previous animal or sewage material.

It is the fashion of certain English chemists to report in absolute figures so much "previous sewage contamination." This involves a fallacy, and little meaning attaches to it. The figures given, in any case, are reached by determining the total amount of nitrogen which is present as ammonia, and also as nitrites and nitrates; after subtracting the small amount of nitrogen which rain-water contains in these forms, there is calculated from the remainder how much of what is called "average London sewage" would be necessary to account for this amount of nitrogen. The composition of the so-called "average London sewage" is not, as might be supposed, deduced from a certain number of examinations made at various times, but the average sewage is taken arbitrarily as containing 10 parts of combined nitrogen in 100,000 parts. Again, when sewage or other nitrogenous matter decays, it depends upon circumstances how much combined nitrogen is set free as nitrogen gas, how much is converted into ammonia, and how much is oxidized so as to appear as nitrites or nitrates. Where the sewage passes through the soil before reaching the river, it may carry into the stream a quantity of nitrates and but little nitrogen in the form of animal organic matter. It seems from recent researches that the

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[1] See the Fourth Annual Report of the Mass. State Board of Health, 1873.

process of nitrification in the soil is brought about by means of an organized ferment, and therefore, under different conditions, may take place with different intensity. Moreover, nitrates once formed are readily reduced in the presence of decaying organic matter, so that the nitrates present at any time give no quantitative indications of the amount of sewage previously present.

While the presence of nitrates under most circumstances indicates that there has been previous pollution, it is often sufficient to apply a qualitative test and to judge from it roughly of the amount present. That most commonly applied is the sulphate of iron (ferrous sulphate) test. A small quantity of the water under examination is mixed in a glass tube with an equal volume of pure concentrated sulphuric acid. The mixture, which becomes very hot, is cooled to the temperature of the air, and there is then poured upon it a solution of sulphate of iron. If nitrates are present, a dark ring or layer forms between the two liquids. The amount of nitrates present may be inferred from the extent to which the water must be concentrated before it will give indications by this test.

Of other inorganic substances it is often necessary to determine whether lead, copper, or other mineral poison is present in appreciable quantity, and also to ascertain, at least approximately, the amount of lime and magnesia, and sometimes of iron. Sufficient information with regard to the lime and magnesia may generally be obtained by determining the "hardness" of the water.

In determining the "hardness" of the water, advantage is taken of one of the properties which make hard water undesirable—namely, the property of destroying soap. A solution of soap is prepared of such a strength that a measured quantity of it is exactly destroyed or neutralized by a known amount of lime. The lime is previously dissolved in a certain amount, say 100 cubic centimetres, of water, and in the case of a water under examination, it is ascertained how much of this same standard soap solution is destroyed by 100 c. c. of this particular water. The hardness of another portion of the water is determined after boiling for some time; this is called "*permanent hardness*," and is due to sulphates and other soluble compounds of lime and magnesia. The total hardness, less the permanent hardness, is the "*temporary hardness*," and is due to the bicarbonates of lime and magnesia which are decomposed by boiling. The hardness is generally expressed in degrees, which have different signification in different countries. In England, where the process originated, a degree of hardness corresponds to a grain of carbonate of lime in one imperial gallon of water; for example, a water of 5 degrees hardness means that each gallon of the water contains 5 grains of carbonate of lime, or an amount of sulphate of lime, or that it contains carbonate or sulphate of magnesia equivalent in soap-destroying power to 5 grains of carbonate of lime. In Germany the degrees of hardness are parts of oxide of calcium (quick-lime) in 100,000 parts of water. In France the degrees mean so many parts of carbonate of lime in 100,000 parts of water. In America, in spite of the anomaly, many express the hardness in English degrees, *i. e.*, in grains to the imperial gallon, while the other results are given in grains to the U. S. gallon. The French system of parts in 100,000 is, however, now coming into vogue.

Organic matter.—In the examination of water there are few inorganic substances to be determined as bearing on the sanitary quality of the water, except in so far as they indicate sewage contamination, and the total amount of inorganic matter may be quite large without rendering the water unwholesome; it is different, however, as we have already seen, with the organic matter.

Since there is disagreement among medical men as to the nature of the injurious substances in polluted water, and since even with regard to decomposing sewage no one knows for a certainty in what its power for harm resides, it is not to be expected that analysis can say with absoluteness of statement whether a given water is *dangerously* polluted or not. Indeed, we may say that chemistry does not give us the means of determining the amount of organic matter in water, or even of determining, in all cases, whether it is of animal or vegetable origin.

There are many persons who suppose that the way to consult a chemist in the matter of water-supply is to send a sample of water in a sealed vessel, with no hint as to its source; and they expect the results of the chemical examination of the water to be accompanied by a statement as to the wholesomeness of the water, or of the possibility of danger from its use. The chemical examination is of great service, and often indispensable; but, except in cases of gross pollution, it is *impossible* to pronounce definitely on the water without a knowledge of the locality from which it is taken.

Now, although the term "organic matter" sounds as if it meant some definite thing, this is not the case. For instance, a pound of sugar, the chemical symbol of which is $C_{12} H_{22} O_{11}$, a pound of albumen, the symbol of which is $C_{72} H_{112} N_{18} SO_{22}$ (?), and a pound of excrement, for which, of course, no symbol could be given, are very different things. Some organic matter contains a large and some a small percentage of carbon; the same is true with reference to nitrogen, to hydrogen, and to oxygen, which make up the bulk of all organic matters. Even if the chemist could say with all assurance that a certain water contained exactly 1 or 2 or 5 parts of organic matter in 100,000, we should be very far from having the data necessary for forming an opinion of the water. But the chemist cannot make any such statement, as will appear from what follows.

The earliest method by which an attempt was made to determine the amount of organic matter was to take the residue of evaporation, the residue whose weight gives us the so-called "total solids," and subject it to the action of a low red heat until all the carbonaceous matter was destroyed. This "loss on ignition" is now generally tabulated as "organic and volatile matter," but it is far from being due entirely to the destruction of the organic matter which may be present. As the determination can be made in a very short time, and as the "total solids" are always determined, the determination is not absolutely valueless. Under certain circumstances it may be of assistance in comparing different waters, or even in judging of a single water which is under examination; but, as a rule, no great value can be attached to the determination, and two different persons would not obtain the same result from the same water, and for several reasons.

In the first place, certain kinds of organic matter are burned up with difficulty. They char at once, but the carbon remains unconsumed, except on application for a long time of a considerable degree of heat. On the other hand, if the heat applied be considerable, there is danger, or rather certainty, of volatilizing alkaline chlorides. Moreover, other salts are decomposed with partial volatilization; thus, the carbonates of lime and magnesia are more or less completely converted into oxides by expulsion of the carbonic acid, or, in the presence of a sufficient quantity of silicic acid, into silicates. The nitrates are converted into carbonates, oxides, or silicates, chloride of magnesium is decomposed in the presence of hydrated compounds with escape of chlorhydric acid, and other changes take place which it is not necessary to particularize.

Many attempts have been made to render this determination of organic matter more reliable, and different chemists use different devices. The practice of the writer is to weigh the residue after drying at 212° Fahr. (100° C.); then to ignite gently, using only a low red heat; then to moisten with water containing carbonic acid and leave for a time, in order that the oxides of calcium and magnesium which have been formed from the carbonates may be reconverted into carbonates, and that the salts which crystallize with water may retake their water of crystallization at least as far as it is retained at 100°; after standing, the residue is again dried at 100° as before, and weighed. The difference between the two weights is tabulated as "organic and volatile matter." In the case of very soft waters, such as those of many New England streams, this difference is really, in great measure, organic matter; the waters contain only a small amount of alkaline salts, almost no nitrates, and only a small amount of carbonates and of alkaline chlorides. In most well waters the determination is valueless.

Owing to the unsatisfactory character of the determination of organic matter by ignition, many attempts have been made to obtain more reliable results by other methods. Several of these methods depend upon the oxidation of the organic matter by means of permanganate of potash, a compound which contains a considerable proportion of oxygen, and which parts with a portion of it quite readily. The solution of permanganate of potash, even if very dilute, has a marked pink color, which disappears when the permanganate has been destroyed by organic matter, and, by successive additions, it may be determined how much permanganate a given bulk of a certain water will destroy. There are various ways of applying the permanganate solution. Some prefer to use the reagent in alkaline, and others in acid solutions; some heat the liquid to one temperature, and some to another.[1] As to the results obtained, it is self-evident that different organic substances require very different amounts of oxygen to burn them up, and consequently that the amount of permanganate employed cannot be taken as an absolute measure of the amount of organic matter. Moreover, some organic substances are not acted upon at all by the permanganate in solution. It is, however, the custom either to report the amount of oxygen as indicated by the amount of permanganate destroyed, under stated conditions, by a given quantity of water, or to multiply by some conventional number and call the product "organischer Substanz." The latter is the common practice in Germany.

Another method of using permanganate of potash to give indications of the character of the organic matter is the so-called ammonia method of water analysis devised by the English chemists, Chapman, Wanklyn, and Smith,[2] and much used in England and in this country. This takes advantage of the fact that certain kinds of nitrogenous organic matter, when treated with a strongly alkaline solution of permanganate of potash, give off a definite portion or the whole of their nitrogen as ammonia; and the value of the method lies in the assumption that it is the nitrogenized organic matter which is to be regarded as the chief source of danger in polluted water. While there is so great difference in the organic matter which may find its way into water-courses, ponds, or reservoirs, there is a general feeling among sanitarians that the most objectionable form of organic matter is that which is highly nitrogenized, or that which, by being readily oxidized, shows itself ready to enter into decay; and if the nitrogenous matter is derived from excremental matter, it is felt that the unknown "something" which causes specific diseases, such as typhoid fever and cholera, may be present.

In working the ammonia-method, the water under examination is put into a retort, made alkaline by means of carbonate of soda, and distilled as long as the distillate carries enough ammonia to be measured by Nessler's solution. Then a solution of caustic soda and permanganate of potash is added, and distillation is continued. Another portion of ammonia now comes off, owing to the action of the permanganate on the nitrogenous organic matter. The amount of ammonia thus obtained is determined, and is tabulated as "albuminoid ammonia," because albumen is one of the bodies which is acted upon in this way.

It is to be said that in the case of some organic substances the action of the permanganate is far from complete, and some are not acted upon with production of ammonia. This method does not reveal anything with reference to carbonaceous matter present, and, indeed, like every other method which has ever been proposed for determining the amount of or-

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[1] See Kubel's Anleitung zur Untersuchung von Wasser, bearbeitet von Dr. Ferd. Tiemann, Braunschweig, 1874. Also a recent paper by Dr. Tidy, Chemical News, XXXVIII., 1878, p. 283.

[2] Water Analysis, by J. A. Wanklyn and E. T. Chapman; 4th Edition, rewritten by J. A. Wanklyn, London, 1876.

ganic matter, the results do not express any fixed and definite thing, as does, for instance, a determination of chlorine. Neither do they tell of the origin of the nitrogenous matter, whether it comes from animal or vegetable sources; in fact, no chemical analysis can tell that unless in exceptional cases. This method is, however, valuable as a means of comparing various waters of the same general character, or of tracing the increase or decrease of impurities of the same sort in the same water.

The second general method in anything like common use is a method devised by Frankland and Armstrong; it was used in the great number of examinations published in the Reports of the Rivers Pollution Commission of Great Britain. The method consists in evaporating a given quantity of the water, under carefully regulated conditions, and in submitting the residue to a process of organic analysis, by which all the carbon is converted into carbonic acid and the nitrogen is liberated in the gaseous state. The mixture of nitrogen and carbonic acid is then analyzed by processes of gas analysis. The results are stated in so many parts of "organic carbon" and so much "organic nitrogen" in 100,000 parts of the water, and sometimes the two amounts together are spoken of as the amount of the "organic elements."

As a chemical process, this method has been made the subject of much criticism by its opponents; from this point of view we can hardly discuss the matter appropriately. As at present employed, in the hands of competent persons, it is calculated to give good results; but the great question is : Of how much value are the results when obtained? The process, in the words of the originator, is "both troublesome and tedious," and requires considerable manipulative skill, the apparatus employed is somewhat costly and frangible, and a good deal of time is unavoidably consumed in the examination.

It is true that, if we have the amount of organic nitrogen and carbon, we come nearer to having the amount of organic matter than is possible by any other means; but, as has been already said, it is, after all, not the amount, but the character, which is to be considered. In this method of analysis, the character and probable origin are inferred from the *relative proportion* of carbon and nitrogen. Thus, in waters which were rendered impure by the presence of extract of peat, the average amount of nitrogen was to the amount of carbon as 1 : 11.9, while the proportion in sewage was as 1 : 1.8.

The influence of oxidation on peaty matter, *i. e.*, vegetable matter containing a considerable proportion of carbon, is to decrease the amount of carbon, while by the oxidation of animal matter, *i. e.*, matter containing a considerable proportion of nitrogen, it is the nitrogen which decreases most rapidly. "It is thus evident that the proportions of nitrogen to carbon in soluble vegetable and animal organic matters *vary in opposite directions during oxidation*—a fact which renders more difficult the decision as to whether the organic matter present in any given sample of water is of animal or vegetable origin."

The average proportion of nitrogen to carbon in various classes of waters, as well as the limits within which the proportion has been observed to vary, is given in the following table:

	Amount of nitrogen	:	Amount of carbon
Peat (one sample)	1	:	11.4
Unoxidized peaty matter in upland surface-water, variation between 1 : 8.2 and 1 : 21.1; average	1	:	11.9
Oxidized peaty matter in lakes, etc., variation between 1 : 3.2 and 1 : 11.4; average	1	:	5.9
Spring-water containing peaty matter, variation between 1 : 1.4 and 1 : 5.4; average	1	:	3.3
Average of a number of samples of fresh sewage	1	:	2.1
Animal matter in polluted wells, variation between 1 : 0.7 and 1 : 6.1; average	1	:	3.1
Average of 16 samples sewage	1	:	1.8
Average of same sewage after oxidation by passing through soil	1	:	4.9

With reference to Frankland's method, Sander says:[1] "Without a knowledge of the previous history of the water, the relative proportion (between carbon and nitrogen) is not available as a means of deciding as to the nature of the contamination; if, however, the previous history of a water is known, there is scarcely need of so particular an analysis in order to judge of its character." For this reason Frankland's method has not been used to any extent in Germany or in this country.

We come now to the interpretation of the results of the analytical examination. Some general principles may be laid down for the interpretation, although, in the majority of cases, chemical examination alone cannot be relied upon as giving conclusive evidence as to the suitability of a water for drinking. Of course, if a water is hard, the chemist can say, without hesitation, that the water is unsuited for supply on account of its probable effect on steam-boilers, and because it will be uneconomical for use in washing. If the water contains arsenic or lead, or other poisonous metal, the chemist can discover it. If the water is grossly polluted, or is of exceptional purity, chemical examination can determine these facts; but, in a vast majority of cases, while chemistry may teach something and aid in the decision, it cannot teach everything, and it cannot *decide*. Now, it would be very convenient, if it were possible, to take each item which is made the object of analytical determination, and say that a good water may contain so much, and if a water contains more, it is not good. This is impossible; a certain amount of the same substance might in one case be a sign of fearful contamination, while in another it might indicate only a normal constituent of the water.

In view of the impossibility of saying exactly what is and what is not harmful, any considerable departure from the normal character of the water in a given locality should be regarded with suspicion. It is true that various students of the matter of water-supply have formulated "standards" which a water may not overpass. They are, however, only

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[1] Handbuch der öffentlichen Gesundheitspflege, p. 230.

of relative value. Moreover, different kinds of water cannot be judged by the same standard, a fact that is often lost sight of.

In considering the various classes of natural waters with reference to the sanitary and especially to the chemical examination, it will be convenient to alter somewhat the order in which they have been studied in a general way as sources of supply. We will begin with the ground-water.

Sanitary Examination of the Ground-water.

In making the preliminary examination of the ground-water of a particular locality with a view to its use for town-supply, the first question that arises is with reference to the quantity of water that can be relied upon. It is true that this question is one which concerns mainly the engineer; as, however, one of the first sanitary requirements is an abundance of water, and, as in many instances, the quantity actually obtained has fallen far short of that anticipated, it is not out of place at this point to emphasize the importance of the preliminary examination. In addition to the knowledge of the amount of rain-fall which can be depended upon in dry years, there must be an intimate knowledge of the locality from which the water is to be taken, of the drainage-area which will contribute to the supply, of the thickness and character of the water-bearing stratum, and of the direction of the movement of the ground-water. The last point, which is important with reference to possible contamination, can often be ascertained by inspection of the region itself and by finding out the slope of the water-table. In case of need, two trial-pits may be sunk in line of the supposed flow, and some easily recognized soluble substance be thrown into what seems to be the upper one. After a time the substance employed may be detected in the second pit, if the flow is really in that direction. It is also important to know whether there are any establishments from which objectionable refuse material is allowed to soak into the ground. The chemical examination of a ground-water proposed for town-supply is mainly directed toward the organic matter or to the evidence of previous pollution, but does not differ essentially from that followed out in the case of shallow wells, as stated below. It should be accompanied by an examination of the stream or pond, if the water is to be taken in the neighborhood of a visible body of water, although, as we have seen, it is generally the case that the stream contributes a relatively small volume of the supply.

Where the ground-water is used from shallow wells by individual families, and, in general, where shallow wells are situated near dwellings, the water is particularly liable to become polluted. Although an inspection of the locality may show that such pollution is possible or even probable, the matter can hardly be decided without chemical examination. It is in the case of well-waters that the chemical examination is of the greatest value from a sanitary point of view. As is the case with the ground-water in general, the total amount of mineral matter is of little account, but any appreciable amount of organic matter is objectionable.

Even if the organic matter were entirely of vegetable origin, it would still be objectionable, for it would show that the well received surface drainage, from which all wells should be protected. A large majority of the shallow wells in actual use are so situated that they receive sewage directly or indirectly. If the sewage be passed through a sufficient amount of soil, the organic matter is completely destroyed, although the evidence of its previous existence remains in the ammonia, nitrites, nitrates, and chlorides. There is oftentimes great difficulty in deciding whether a well-water should be condemned for use or not. On the one hand, if there is any considerable amount of unchanged organic matter, it is detected at once; and, on the other hand, the absence of organic matter, of ammonia, and of an abnormal amount of chlorides, shows that the well receives no appreciable amount of sewage. The majority of well-waters, however, lie between these two extremes and fall into the category of suspicious waters, with reference to which it is impossible for even the experienced observer to pronounce definitely without an intimate knowledge of the locality—and sometimes not even then.

The following table contains the results of the examination of ground-water of good quality from two localities, where it is true that the neighboring stream probably contributes some portion of the water. The table also contains the results obtained from the examination of a number of samples of well-waters, the organic matter being indicated by the so-called "albuminoid ammonia."

EXAMINATION OF GROUND-WATER.

(Results expressed in Parts in 100,000.)

LOCALITY AND DATE.	Ammonia.	"Albuminoid Ammonia."	RESIDUE.			Chlorine.	Nitrates.	Remarks.
			Inorganic.	Organic and volatile.	Total at 212° F.			
GROUND-WATER.								
Lowell, Mass., Sept. 2, 1873........	0.0013	0.0027	4.84	1.80	6.64	0.24		
" Jan. 2, 1874........	0.0063	0.0037	5.20	1.20	6.40	0.26		
Waltham, Mass., Nov. 18, 1873......	0.0013	0.0033	5.20	1.20	6.40	0.44		
" Dec. 16, 1873......	0.0047	0.0056	5.60	0.92	6.52	0.38		
SHALLOW WELLS.								
Lynn..............................	0.218	0.022	....	[12.0]	77.	11.6	Large am't.	Bad.
Belchertown.......................	0.0059	0.0044	....	[1.8]	22.56	3.56	Trace.	Suspicious.
Chicopee..........................	0.0027	0.0069	....	[4.6]	50 52	11.72	Small am't.	Suspicious.
Milford...........................	0.7253	0.0395	....	[8.2]	48.48	8.62	Large am't.	Very bad.
Taunton...........................	0.0037	0.0093	....	[2.8]	31.12	3.20	Trace.	Suspicious.
" (another)................	0.1066	0.0136	....	[1.8]	44.92	10.20	Trace.	Bad.
Fitchburg.........................	0.0128	0.0011	....	[1.2]	15.35	3.9	Trace.	Suspicious.

In case of shallow wells, we must regard with suspicion a water which contains from 0.006 to 0.01 parts of ammonia, from 0.006 to 0.01 parts of "albuminoid ammonia," and say 1.0 part of chlorine; suspicion is also awakened by any appreciable amount of nitrites and nitrates—enough to show their presence in the unconcentrated water by the sulphate of iron (or ferrous sulphate) test. The amounts mentioned would not justify a condemnation of the water, especially if the limit were exceeded in one particular only; but they would lead to inquiry as to the location of the well, and as to a possible explanation of the apparently abnormal quantity of whatever excited the suspicion. The suspicions thrown upon the character of the water lead also to renewed chemical examination. This is quite important, for a single sample of water hardly gives a fair idea of the general character of the well. It often happens that a well shows periodic contamination—that is, at certain times polluting liquid reaches it, and not at others. Where frequent complete analyses are not possible, it is a quite satisfactory method of examination to determine from time to time the amount of some one substance present. Take, for instance, chlorine. It may be that the chlorides in a well-water are abnormally high because salt has been used to thaw out the pump or has been scattered about the well to kill weeds; in such cases, any suspicion excited by the presence of chlorine is allayed when the circumstances are known. As a rule, however, the chlorides come from cesspools or vaults; and as chlorine is easily determined, it may be selected as the object of a number of consecutive examinations. In this way it is possible to ascertain whether the water is subject to much variation, and a more particular examination can be made at times when the chlorine proves to be present in larger proportion than usual. If a particular vault or cesspool is suspected, it is advisable to throw a quantity of strong brine (*i. e.*, a solution of chloride of sodium) into the suspected source of contamination, and observe whether, and after how long an interval, the proportion of chlorine in the well shows an increase. Salts of lithium are also used for the same purpose, as a very minute amount of lithium can be detected by the spectroscope.

With regard to the determinations other than those mentioned above, it may be said, that in order to make the determination of the "total solid residue" of any value, something must be known of the geological character of the region or of the water of wells known to be unpolluted. As much as forty or fifty parts of total solids in 100,000 parts of the water may often be allowed in drinking-water, provided they are of such a character as to be harmless; but, in the case of shallow wells supplied from the ground-water, such an amount could be considered admissible only under very peculiar circumstances; it might perhaps be allowed in wells near the sea.

The "loss on ignition," or the so-called "organic and volatile matter," is of no value whatever in the case of well-water or of other waters giving a considerable amount of solid residue; this is especially the case when there is a large proportion of chlorides and nitrates. In the table on p. 305, the loss which the various residues suffered when heated are given in brackets, but the figures are of no use in forming an opinion of the various waters. It may, however, be said that the residue of a well-water should not blacken when ignited; and often the odor of the burning organic matter betrays its origin.

The amounts of "organic carbon" and "organic nitrogen" in unpolluted well-waters are very small, and should not exceed 0.02 part for the nitrogen and 0.20 part for the carbon. The following table[1] contains the results of the examination of some well-waters by Frankland's method:

	Organic carbon.	Organic nitrogen.	Ratio. $\frac{\text{Carbon}}{\text{Nitrogen.}}$	Ammonia.	Nitrogen as nitrites and nitrates.	Chlorine.	Remarks.
A...	1.820	0.710	2.5	0.120	0.400	7.10	Horribly polluted.
B...	0.177	0.017	10.5	0.004	0.184	2.72	Good.
C...	0.181	0.037	5.	.....	3.76	15.5	Good.

Sanitary Examination of Deep Wells.

In the case of deep wells and springs there is less likelihood of contamination than in the case of shallow wells, as has already been seen. The chief danger arises from surface drainage, the likelihood of which can generally be estimated from an inspection of the surroundings, and from which the wells can generally be protected.

In regard to the "albuminoid ammonia" and to the organic carbon and organic nitrogen, the same rules will apply as in the case of shallow wells; but in the case of deep wells the total solid residue, the chlorine, the ammonia, and the nitrogen as nitrites and nitrates, are of no value as tests of impurity, since unpolluted deep water often contains considerable quantities of one or more of these substances.

In the case of deep wells, however, more importance attaches to the particular analysis of the dissolved solids than in the case of any other class of water. It is almost always true that the water contains a comparatively large amount of saline matter, and it is important to ascertain the proportion of the various salts which make it up. Especially to be avoided are sulphate of lime and the sulphate and other salts of magnesia. Of course this has reference to the continued use of the water. Some waters containing a quantity of purgative salts may be valuable as medicinal agents, but are unsuited for daily use. It is important also to know the hardness of deep-well waters if the water is intended for a general supply and not simply for drinking.

The following table contains some of the results presented by the Rivers Pollution Commission in their Sixth Report. The figures given are averages; of course there is a very considerable variation among the individual wells, but the averages will be more instructive than the same number of examinations of particular wells.

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[1] From Fox's Sanitary Examination of Water, Air, and Food.

EXAMINATION OF UNPOLLUTED WATER FROM DEEP WELLS.

(Frankland's method. Results expressed in parts in 100,000.)

GEOLOGICAL FORMATION.	Total solid impurity.	Organic carbon.	Organic nitrogen.	Ammonia.	Nitrogen as nitrates and nitrites.	Total combined nitrogen.	Previous sewage or animal contamination.[1]	Chlorine.	HARDNESS.			No. of samples.
									Temporary.	Permanent.	Total.	
Devonian rocks and Millstone Grit.......	32.68	0.068	0.012	0.005	0.294	0.310	2671	2.70	8.8	8.6	17.4	7
Coal-measures.........	83.10	0.119	0.034	0.044	0.267	0.278	2243	18.05	15.1	20.6	35.7	9
Magnesian Limestone..	61.14	0.076	0.030	0	1.426	1.456	13937	4.31	16.9	26.9	43.8	3
New Red Sandstone....	30.63	0.036	0.014	0.003	0.717	0.734	6895	2.94	7.4	10.5	17.9	28
Hastings Sand, etc.....	45.20	0.068	0.014	0.016	0.196	0.223	1864	5.38	16.8	10.5	27.3	20
Chalk...	36.88	0.050	0.017	0.001	0.610	0.628	5801	2.76	21.2	6.5	27.7	66

Sanitary Examination of Surface-waters.

With the views which are at present held with reference to the danger from the pollution of lakes and streams by sewage and other refuse substances, the most important part of the sanitary examination of such sources of supply is the inspection of the locality from which the water is to be taken and of the surroundings. If the stream or lake receives, in proportion to its size, any considerable amount of sewage or of manufacturing refuse, it should be rejected as a source of supply independent of any chemical examination. The principal difficulties in the way of the satisfactory chemical examination of surface-waters are three in number: In the first place, the volume of water is generally so large that, even when polluting matter is known to be present, the dilution is so great as to prevent the detection of unmistakable evidence of contamination. In the second place, all surface-waters contain more or less of organic substances—substances containing carbon and nitrogen—which it is impossible to refer definitely to animal or vegetable sources, or otherwise to distinguish as harmless and harmful. In the third place, the water of such streams and ponds is subject to very considerable variation, so that the examination of a single sample is of comparatively little value. It may be possible, it is true, to state from the chemical examination of a single sample that no considerable or no appreciable contamination exists; it is impossible to recommend a water for drinking without knowing something of the situation and surroundings of the source from which it is taken.

The following statements will serve to illustrate the variations to which river and pond waters are subject. Weekly examinations of the water supplied to the city of Boston were made from July, 1876, to June, 1877, inclusive. The ammonia varied from 0.0005 to 0.0056, the "albuminoid

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[1] These figures will serve to show the fallacy of the so-called "previous sewage contamination." See page 297.

ammonia" from 0.0099 to 0.0176, the total solids from 3.72 to 5.58, all these results being expressed in so many parts in 100,000. In like manner, examinations were made nearly every week during the year 1877 of the water of the Ludlow reservoir, a recently flowed artificial pond, which forms the larger portion of the supply of Springfield, Mass., and which has every summer a copious growth of microscopic algæ. The ammonia varied from 0.0024 to 0.0403; the "albuminoid ammonia" in the unfiltered water, from 0.0173 to 0.0899; in the water after filtration through paper, from 0.0160 to 0.0432; and the total solids, from 3.36 to 6.72. A similar variation is shown in the monthly examinations which are made of the Thames water, in London. The following figures show the variation in the case of one of the London companies, the Chelsea, during the year 1873:[1]

Total solids..................	from 25.26	to 29.72,	the mean being	27.32
Organic carbon..............	"	0.121 to	0.447,	"	0.197
Organic nitrogen............	"	0.013 to	0.067,	"	0.034
Nitrogen as nitrates and nitrites	"	0.148 to	0.389,	"	0.225
Chlorine....................	"	1.80 to	2.20,	"	1.93
Hardness....................	"	18.9 to	22.7,	"	20.8

It is very evident from these figures that, although something may be learned from the results of a single examination, in order to have any complete or satisfactory idea of the character of surface-water a series of examinations is necessary, so as to cover the various seasons of the year and other changes in the conditions.

EXAMINATION OF SURFACE-WATERS.

(Frankland's method. Results expressed in parts in 100,000.)

GEOLOGICAL FORMATION.	Total solid impurity.	Organic carbon.	Organic nitrogen.	Ammonia.	Nitrogen as nitrites and nitrates.	Total combined nitrogen.	Previous sewage or animal contamination.	Chlorine.	HARDNESS.			No. of samples.
									Temporary.	Permanent.	Total.	
Igneous rocks....	5.15	0.278	0.033	0.001	0.002	0.035	0	1.13	0.1	2.0	2.1	18
Metamorphic, Cambrian, Silurian, and Devonian...........	5.12	0.293	0.024	0.002	0.006	0.031	0	0.92	0.3	2.5	2.8	81
Yoredale and Millstone Grits and non-calcareous Coal-measures..	8.75	0.377	0.033	0.003	0.010	0.050	0	1.05	0.4	4.3	4.7	47
Calcareous portion of Coal-measures.......	22.79	0.346	0.037	0.003	0.016	0.056	33	1.52	4.0	8.3	12.3	26
SURFACE-WATERS FROM CULTIVATED LAND.												
Non-calcareous districts...............	9.52	0.276	0.034	0.007	0.089	0.128	635	1.49	0.6	4.3	4.9	31
Calcareous districts....	30.08	0.268	0.053	0.005	0.257	0.314	2306	2.24	12.4	8.2	20.6	124

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[1] Sixth Report of Rivers Pollution Commission.

As to the interpretation of the particular results, surface-waters cannot be judged by the same rule as well-waters.

While in the case of shallow wells suspicion is awakened by the presence of from 0.006 to 0.01 parts in 100,000 of ammonia or of "albuminoid ammonia," in the case of rivers which flow through peaty regions these figures will be almost always greatly exceeded; and while the determinations themselves are not without value, they can be interpreted only in the light of a knowledge of the history of the water. The table on the preceding page will furnish some idea of the results obtained in the examination of surface waters by Frankland's method. The figures given were obtained by the Rivers Pollution Commission as averages, from the examination of a considerable number of samples from various geological formations.

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PHYSICAL EXERCISE.

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PHYSICAL EXERCISE.

IF we adopt Béchard's definition of life as "organization in action," perfect health may be described as that condition in which the various functional activities of the body are carried on with their normal energy and in a harmonious manner. For the maintenance of such a condition of the vital powers a certain amount of physical exercise is indispensable, since the functions of respiration and of the circulation of the blood, which largely control the assimilative and disassimilative processes of the body, are directly and powerfully influenced by the activity or inactivity of the muscular system.

EFFECTS OF EXERCISE.

1. *Local phenomena of muscular action.*—The property of contractility, by means of which the muscles convert latent energy into mechanical motion, is inherent in the muscular substance itself, but in normal life the manifestation of this property is immediately determined through the influence of the nervous system. Of this "nervous influence" nothing is known except that it appears to consist of a wave of molecular disturbance travelling along the nerves to their terminal expansions in the muscular fibres at the rate of 33 metres per second, and marked in its progress by a diminution of the electrical current, detected by the galvanometer in quiescent nerve (the "negative variation" of Du Bois-Reymond). On its arrival at the muscular fibre the nervous impulse is converted into muscle-impulse; in other words, the molecular wave in the nerve sets in motion a wave of molecular disturbance in the muscle, traversing the fibre in both directions from the insertion of the end-plate of the nerve at the rate of about three metres per second,[1] its progress being marked by a negative variation of the natural electrical current of muscle. Between the reception of the nervous impulse and the initiation of the visible contractile movement an interval of about $\frac{1}{100}$ of a second elapses, known as the "latent period" (Helmholtz), which is probably occupied by molecular changes in the fibre preparatory to its alteration in form. At the close of the latent period the muscle-impulse is succeeded by a wave of *contrac-*

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[1] Bernstein: Untersuch. über den Erregungsvorgang im Nerven- und Muskelsysteme, 1871.

tion, having the same starting-point, the same double direction, and about the same velocity, and occupying about $\frac{1}{10}$ of a second in its transit. Contraction of the individual fibres produces changes in form of the entire muscle, viz.: shortening and thickening with a trifling reduction in bulk (about $\frac{1}{1000}$ part). Each voluntary muscular contraction, moreover, is compound in character, being composed of a series of rapid contractions, due to an equally rapid succession of nerve-impulses (Weber).

The electrical change, known as negative variation, which takes place during contraction, is variously explained according to different theories of muscular action. Du Bois-Reymond supposes that electrical *currents* are constantly generated in living muscle, positive electricity appearing on the longitudinal surface of the fibres and negative electricity at their ends. During contraction the currents are very much diminished, and, to account for this fact, Du Bois-Reymond has advanced the following hypothesis: muscular tissue, he supposes, is composed of a great number of movable molecules, each of which has two negative poles and a positive equator. During muscular rest the negative poles are directed toward the ends, and the equators toward the longitudinal surfaces of the fibres, total currents being thus produced by the union of the numerous smaller ones. During contraction, however, a partial rotation of the molecules takes place, bringing the negative pole of one molecule into contact with the positive equator of its neighbor, so that the currents are less noticeable at the surface of the muscle, because they are almost entirely retained within its substance. This theory, which is accepted by most physiologists as a provisional hypothesis, is strongly opposed by Dr. C. B. Radcliffe,[1] who maintains that the electrical condition of muscle is not current, but *static*, the so-called muscle-current being, in his opinion, merely an accidental phenomenon produced by applying the electrodes of the galvanometer to points of dissimilar tension. Briefly stated, his view of muscular action is as follows (p. 98): (1) "The state of relaxation is brought about by the charge of electricity present in the muscle during the state of rest, the mutual attraction of the opposite electricities disposed on the two surfaces of the sheaths of the fibres elongating the fibres by compressing the sheaths at right angles to their surface; and (2) the state of contraction is caused by the discharge of the charge of electricity present during the state of rest, the discharge leaving the fibres free to return, by virtue of their elasticity, from the state of elongation into which they had been forced by the charge." According to this view, therefore, the sheaths of the muscles act as so many charged Leyden jars, and the so-called negative variation is in reality due to the occurrence of an electrical discharge. The theory is, however, open to the following objections: (1) There is no proof that the sheath of muscular fibre is a sufficiently bad conductor to serve as a dielectric, as is the case with the glass of the Leyden jar; (2) neither the cardiac muscle nor unstriped muscular tissue possesses a sarcolemma, or any covering which can fairly be said to correspond to it; and (3) the so-called negative variation occurs *before* contraction begins, and disappears as soon as the visible contractile movement is initiated—a circumstance, which, according to the "discharge" theory, involves the necessity of supposing that a charge of electricity reaccumulates at the very moment when contraction actually takes place.

The molecular vibrations accompanying the contractile movements give rise to a distinctly audible sound, the *muscular susurrus*. Attention was first called to this phenomenon by Dr. Wollaston,[2] who described it as resembling most nearly the sound produced by "carriages at a great dis-

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[1] Dynamics of Nerve and Muscle, 1871.

[2] Croonian Lecture before the Royal Society, Nov. 16, 1809.

tance passing rapidly over a pavement," and stated that it is best heard by inserting gently the extremity of the finger into the ear, bringing at the same time the muscles of the hand and forearm into strong contraction. The rate of vibration, as first investigated by Collingues[1] and Haughton,[2] independently of each other, was determined to vary from 30 to 36 per second. The more recent investigations of Helmholtz[3] show, however, that while the note heard corresponds to 36 to 40 vibrations per second, this tone is really a harmonic of the primary note, and that the latter represents only 18 to 20 vibrations per second. In partial paralysis and exhaustion of the muscles the note is lower in pitch, and the rate of vibration may fall to 6 or even 4 per second.[4]

The *temperature* of muscle falls slightly at the outset of contraction, probably in consequence of the increased specific heat of contracted muscle (Heidenhain), but afterward rises above the temperature of muscular repose, and continues to increase for a time after the cessation of the contraction (Thiry, Myerstein).

As regards *vascular* changes, it has been demonstrated by the recent experiments of Gaskell[5] that the flow of blood through muscle is *increased* during the period of contraction. This observer found that stimulation of the peripheral end of the divided nerve belonging to a muscle produces not only physiological tetanus, but also a marked increase of the rate of flow through the muscle; which increase, with prolonged stimulation, takes place even during tetanus itself, and is doubtless due to dilatation of the arterioles of the muscle. By means of the hydrosphygmograph, Mooso has ascertained that an increased flow of blood through muscle takes place also during *voluntary* muscular contraction.[6]

As the capillary vessels of muscle run between the elementary fibres, the amount of blood-supply (and consequently the capacity for prolonged work) must vary, for the same bulk of muscle, in proportion to the smallness of the fibres. In women the fibres are of smaller size than in men, and Haughton (op. cit., p. 3) claims to have found by direct experiment that "the muscles of women are capable of longer continued work than those of men, although inferior to them in force exerted for a short time." He adds: "If any man wishes for a simple proof of the inferiority of the endurance of his muscles as compared with those of a woman, let him carry a child on his arm for the same time that his wife or nurse can do so with ease, and he will find himself much fatigued."

That important *chemical changes* take place in muscle during contrac-

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[1] Traité de Dynamoscopie, Paris, 1862.

[2] Thesis for Medical Degree in the University of Dublin, 1862.

[3] Ueber das Muskelgeräusch, Monatsber. der Kgl. Akad. d. Wissensch. zu Berlin, 1864, p. 307; and Ueber d. Muskelton. Verhandl. d. Naturforsch. Med. Ver. zu Heidelberg, Bd. IV., 1866, p. 88.

[4] Haughton: Principles of Animal Mechanics, 1873, p. 23.

[5] Ueber die Aenderungen des Blutstromes in den Muskeln durch die Reizung ihrer Nerven. Arbeiten der Physiol. Anstalt zu Leipzig, XI. Jahrg., 1876. Also Journal of Anat. and Physiol., Vol. XI., p. 360 and p. 720; and Journal of Physiology, 1878, Nos. IV. and V., p. 262.

[6] Sulle Variazioni locali del polso nell' antibraccio dell' uomo, Turin, p. 59.

tion is highly probable, but our present knowledge upon the subject is in a very fragmentary condition. The blood escaping from muscle during contraction is much darker than the venous blood of muscular repose, and is found to contain a much larger proportion of carbonic acid. This excess of carbonic acid is considerably greater than can be accounted for by the amount of oxygen absorbed during the period of contraction, and must be derived, therefore, not from a direct process of oxidation at the time, but from a splitting up of compounds in which oxygen had been previously stored. Sarcolactic acid is also formed in quantities sufficient to change the reaction of the muscular substance from neutral or alkaline to acid. With respect to other products, the observations are less satisfactory. Helmholtz[1] found that when a frog's muscle was tetanized to exhaustion the fixed substances dissolved in the fluid expressed from the flesh differed from those obtained from the similar muscle which had been left in repose; the extractives soluble in water were diminished, while those soluble in alcohol were increased. In Ranke's experiments a diminution of albumen was observed, with a production of fat and sugar; the latter, it has been suggested, may have been formed by conversion of the glycogen present in quiescent muscle. The absence of any marked increase in the *nitrogenous* products of disassimilation in muscle during exercise is especially noteworthy. To be sure, J. von Liebig claimed many years ago to have found an increase of kreatin in the muscles of hunted animals, and Sarakov states that this substance and kreatinin are doubled in the muscles of frogs by tetanization, but both observations remain unsubstantiated. Urea, except occasionally in very minute quantities, is absent from the muscles during both rest and contraction.

The source of muscular power and the development of muscles by exercise will be considered later.

2. *General effects of exercise.*—a. *On the respiration.*—The most important changes produced in the respiratory function by muscular exercise are: acceleration of breathing, increased absorption of oxygen, and increased elimination of carbonic acid and water. During continued exercise the acceleration of breathing and the quantity of air inspired usually correspond to the amount of mechanical work performed.[2]

The following table, abridged from the results of Dr. Edward Smith's experiments,[3] gives the relative quantities of air inspired during various forms of muscular exertion, the amount inspired in the recumbent position at rest being taken as unity:

Sitting posture	1.18
Standing "	1.33
Walking one mile per hour	1.9
Riding on horseback at walking pace	2.2
Walking two miles per hour	2.76

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[1] Müller's Archiv, 1845.

[2] A notable exception to this rule occurs in rowing (see p. 354).

[3] Health and Disease, 1861, p. 300.

Riding on horseback at cantering pace	3.16
Walking at three miles per hour	3.22
“ “ “ and carrying 34 lbs.	3.5
“ “ “ “ 62 “	3.84
Riding on horseback at the trotting pace	4.05
Swimming	4.33
Walking at three miles per hour and carrying 118 lbs.	4.75
“ four “ “ “ “	5.0
The tread-wheel	5.5
Running at six miles per hour	7.0

With respect to the pulmonary elimination of carbonic acid during exercise, as compared with rest, the experiments of the same author give the following results:[1]

		Proportions with rest as unity.
During rest	13.11 grains per minute.	1
Walking at 2 miles per hour and carrying 7 lbs.	24.26 “ “	1.85
Walking at 3 miles per hour	34.66 “ “	2.64
On tread-wheel, when lifting 196 lbs. through 1920 feet per hour.	57.68 “ “	4.40

He also gives the following general estimate of the daily amounts of carbonic acid expired by the non-laboring and laboring classes:

	Grains.	Proportions with rest as unity.
In rest with 2½ hours' standing	11.427–56	1
Non-laborious class, with three hours' walking at 2 miles, and 1 hour at 3 miles per hour	14.572–38	1.27
Laborious class, three times the above addition.	18.732–79	1.63

The experiments of Pettenkofer and Voit upon the elimination of carbonic acid and absorption of oxygen during rest and exercise were conducted with the aid of apparatus, which secured a higher degree of accuracy than was attainable by previous methods of investigation. The following table gives the results in abridged form:[2]

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[1] Op. cit., p. 293.

[2] Zeitschrift für Biologie, Bd. 11, p. 546. A large respiration-apparatus was used, in which the subject of experiment remained for twenty-four hours. The above table includes only the experiments made without alteration of diet. They were five in number, three during rest-days, and two during work-days. During the rest-days the man, a watchmaker, either read or amused himself by taking apart and cleaning

Average elimination of carbonic acid in grains.			Average absorption of oxygen in grains.	
	Day.*	Night.	Day.	Night.
Rest..................	8825.25	6100.73	5771.56	7062.60
Work...............	13217.50	5447.49	8410.44	6720.63
Work-day...........	+4392.25	−653.24	+2638.88	−341.97

If the amount of carbonic acid eliminated and oxygen absorbed during rest be respectively taken as unity, the average gain during the work-days was:

Day-hours.		Entire 24 hours.
Carbonic acid eliminated....................	1.6	1.
Oxygen absorbed..........................	1.45	1.2

The amount of aqueous vapor in the expired air is also largely increased by exercise.

b. *On the circulation.*—During moderately energetic exercise the heart beats more frequently and forcibly, the arteries dilate, and a larger stream of blood is propelled through the body, but especially to the muscles where the increased flux is required. If the exertion be very severe, the cardiac contractions become still more frequent, feebler, and finally irregular, while at the same time a peculiar form of dyspnœa is experienced, which is familiarly known as "loss of wind." This distress in breathing is produced by disturbance of the equilibrium between the respiratory and the circulating organs, the disturbance in question being the combined result of several causes. In the first place, energetic contraction of the muscles, as is well known, accelerates the venous circulation, and thus determines an increased flow of blood to the right side of the heart.

The explanation commonly given of this result, viz., that the acceleration of the venous current is chiefly due to compression of the veins running between the primitive muscular fibres, is based upon a misconception of the actual vascular changes which occur in the muscles during contraction. Thus, it is commonly held that muscular contraction produces the double effect of favoring the return current through the muscular veins, and of obstructing the flow through the muscular arteries. On the

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watches. On work-days he exercised for nine hours a day by turning the crank of a wheel loaded with a weight sufficient to make the resistance at the axle about equal to the resistance of the turning-lathe in his workshop. The labor (7,500 revolutions per day) occasioned moderate fatigue.

[1] Day and night represent here periods of twelve hours each.

contrary, it is highly probable that no compression of the veins occurs in muscles in which the vessels run parallel to the fibres, while, as regards the arteries, the experiments of Gaskell (p. 319) have demonstrated that the arterial circulation of muscle is really *increased* during the period of contraction. The increased flow of blood, escaping from muscle during contraction, is the direct result, therefore, of an increased arterial afflux. At the same time, although the muscular veins themselves probably escape compression by the contracting muscle, the large veins running in its immediate neighborhood are pressed upon by the thickened muscular mass, and their contents propelled by the pressure exerted.

In extreme exertion, moreover, the heart is further embarrassed, as Clifford Allbutt has pointed out, by the action of the respiration. At the end of a deep inspiration, especially if the breath be held for a time, the increased pressure of the air upon the inner surface of the air-cells impedes the flow of blood from the right side of the heart, while the compression of the heart itself, by the distended lungs, tends first to overfill the cavæ and innominate veins, and afterward, when the pressure is removed, to still further engorge the right auricle and ventricle. During general muscular contraction, moreover, as has been demonstrated by Traube, the arterial pressure is increased at the outset of the exertion, before the arteries have become relaxed, and this in turn may lead to distention of the left cavities of the heart and engorgement of the pulmonary circulation. To these causes may be added another, viz., exhaustion of the respiratory muscles, partly as a direct effect of the unusual labor thrown upon them, and partly in consequence of an inadequate supply of properly oxygenated blood. If the disturbance of the pulmo-cardiac equilibrium be severe, and continue unrelieved, general prostration ensues long before the muscles engaged in the work are exhausted. If, on the other hand, the equilibrium be restored, as is commonly the case when the disturbance is slight, or when the lungs and heart have been previously trained to accomplish the restitution, the distress disappears, and the individual is then said to have gained his "second wind," which enables him to continue the exertion up to the limits of muscular exhaustion.

c. *On the cutaneous secretion.*—During active exercise the skin flushes from dilatation of the cutaneous vessels, and a more or less copious transpiration of water takes place, containing chloride of sodium and other inorganic salts, fatty acids and neutral fats. The evidence in regard to the presence of urea is conflicting; the careful investigations of Ranke[1] and others, however, render it improbable that any appreciable amount of urea escapes in the sweat during health.

The quantity of water escaping by the skin during exercise has never been accurately determined, irrespective of that eliminated by the lungs. Funke's experiment of collecting the sweat from an arm surrounded by a caoutchouc bag is open to obvious objections. Pettenkofer and Voit, in the experiments previously referred to, found that with moderate exertion the quantity of water passing off through both lungs and skin was more than doubled. In severe work this ratio is very considerably increased.

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[1] Pflüger's Archiv, VI., 1872.

Maclaren[1] found that in his own case the average loss by respiration and perspiration during six consecutive days, after an hour's energetic fencing, amounted to about three pounds, or, accurately, forty ounces, with a varying range of eight ounces. We are informed by members of a university boat-crew that, during their racing practice in hot weather, the long afternoon pull not infrequently lowered the body-weight by from four to six pounds; and in another instance, for which we have good authority, a student in an English university, with the view of obtaining a position on the university crew, reduced his weight twelve pounds by a single long run in heavy clothing. These losses are, of course, usually replaced in a few hours by copious drinking.

So long as the transpiration and evaporation of water take place freely the *temperature* of the body rises but little during exercise, and in fact may even fall slightly below the normal. After cessation of work the cooling of the body continues for a time, and depresses the temperature temporarily by one or more degrees. If the skin acts imperfectly the heat generated by muscular contraction accumulates in the body, excites languor and other febrile symptoms, and thus indisposes to a continuance of the exertion.

d. *On the digestive system.*—Corresponding to the increased waste there is an increased demand for food, manifesting itself in improved appetite and more rapid digestion and absorption. During its later stages digestion is favored by the vigorous abdominal circulation incidental to active exercise, and probably also by the more frequent concussions to which the abdominal viscera are subjected by the action of the diaphragm in hurried respiration. On the other hand, exercise taken soon after a meal tends to retard digestion by preventing the necessary flux of blood to the stomach, as well as by prematurely expelling the contents of the stomach into the intestinal canal.

e. *On the functions of the nervous system.*—The effect of *moderate* muscular exercise in improving the tone of the nervous system is so patent to common observation as to require no special discussion here; the result, however, of systematic *severe* physical exertion upon the *mental* powers, is not so evident. Does a *large* expenditure of energy in the direction of the muscles appreciably diminish the stock of energy available for the purely mental functions? The question certainly merits careful attention, in view of the recent remarkable growth of athleticism in Great Britain and this country, particularly among those engaged in more or less intellectual pursuits. The common objection to athletic exercises, drawn from the proverbial stupidity of professional athletes—whom Plato described as "sleeping away their lives"—has obviously no direct bearing upon the point at issue. Functional activity, whether of the brain or muscles, *is conditional upon the performance of work*, and the natural tendency of any mode of life that cultivates the physical, to the almost total neglect of the mental powers, must be to induce deterioration of

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[1] Training, in Theory and Practice, London, 1874.

the latter. It is equally clear, also, that indisposition to mental exertion will be experienced during a course of systematic exercise, whenever the exertion is pushed to the point of producing a state of general depression, such as occasionally results from "over-training." About these facts there is no dispute ; the question is rather, whether *carefully regulated* physical exertion—in such amount, for instance, as is necessary to prepare healthy young men for engaging in the severer athletic contests (boat-racing, foot-ball, etc.), tends to produce aversion to, or disqualification for, mental work. That no such *general* tendency is observable in the class of persons most likely to exhibit it, viz., students who devote considerable attention to athletic exercises, has been clearly shown, at least for the English universities, by the investigations of Mr. R. F. Clarke, formerly Fellow and Tutor of St. John's College, Oxford,[1] and Dr. J. E. Morgan, of Manchester, England.[2] It appears from their inquiries that both at Oxford and Cambridge, and particularly at the latter university, the rowing-men and cricketers have obtained more than their proportional share of academic honors. No statistics of like character have been compiled for this country ; but we are satisfied, from personal observation and numerous inquiries, that a similar investigation for our own colleges would elicit an equally favorable result. To be sure, an excessive devotion to athletic sports undoubtedly leads to the waste of much time that ought to be spent in study ; but such an expenditure of time is unnecessary, and is not contemplated in the present remarks. Dismissing this side issue, it remains to be considered whether the amount of muscular exercise indicated in our previous statement of the point at issue has any direct tendency to diminish the power of mental application. Now, it is to be borne in mind that, while it is one of the objects of a course of training to cultivate muscular strength, it is equally an object to maintain the other organs of the body in a condition of perfect health; indeed, the highest degree of muscular strength is obtained only when the general nutrition is carried on with the greatest activity. That the brain must share in the general improvement of nutrition, at least in so far as a generous supply of nutrient material is concerned, and that it should be able to respond to any reasonable demand upon its functional activity, is certainly no more than might be expected from known physiological laws. It may safely be conceded, therefore, that, *with proper precautions,* great bodily is entirely compatible with great mental activity—but only with proper precautions : *the candle must not be burned at both ends.* Exhausting exercise cannot be followed by an excessive drain upon the energies of the mind without danger of the most serious consequences.

A word, in conclusion, with reference to the influence of systematic physical exercise in developing *volitional* power, and in this way cultivating important traits of character. Vigorous muscular exertion, especially when pushed to the point of fatigue, demands a vigorous exercise of the

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[1] Pamphlet on the Intellectual Influence of Athleticism, 1869.

[2] University Oars, etc., London, 1873.

will; a consciousness of increased power is thus acquired, and this in turn begets self-confidence, resolution, and courage—qualities which, if rightly directed by proper moral and intellectual training, elevate the tone of the entire character, and aid to an important degree in subduing the passions. Indeed, the more perfect control which the mind possesses over a vigorous than over a morbidly sensitive body, is a matter of everyday observation, and has given rise to Rousseau's seeming paradox: "the weaker the body, the more it commands; the stronger it is, the more it obeys."[1] It is unnecessary to pursue this line of thought farther, but it may be interesting to note that the conception here given, of physical exercise as a training for the mind no less than for the body, lay at the foundation of Plato's views of the real function of gymnastic exercises in the education of Greek youths.[2] The toils and exercises of gymnastics, he says, if overstrained, are likely to make men hard and brutal; but, if properly regulated, stimulate the spirited element of their nature, make them valiant, and discipline their passions.

f. *On the generative functions.*—The immediate effect of vigorous exercise upon the generative organs is to diminish the sexual impulse by diverting nervous energy into other channels; hence the relief afforded by active exercise in cases of morbid sexual irritability arising from the use of stimulating food and a life of idleness. Remotely, the generative system, equally with other organs, is invigorated by systematic exercise.

g. *On the urine.*—The effects of active exercise upon the urine have been studied by numerous observers, and with tolerably uniform results, except as regards the elimination of urea. The aqueous portion of the urine (except when water has been drunk freely during the exertion) and chloride of sodium are diminished, in consequence of the increased excretion of these substances by the skin; on the other hand, the uric acid, the sulphuric and phosphoric acids and the pigment are increased. Of the bases—soda, potash, lime, and magnesia—the two former are discharged in greater excess than are the two latter.[3] With respect to the nitrogenous elimination during exercise, as measured chiefly by the urea discharged, the results of observation are so discrepant that it is difficult to reconcile them with the accuracy of any general conclusions upon the subject. A brief sketch of the more important experiments may be of interest. J. F. Simon (1842)[4] found the urea slightly increased in consequence of persevering exercise. These experiments were conducted without reference to the nature of the diet. A similar result was obtained by the researches of C. G. Lehmann (1844).[5] The diet being nearly the same, his average excretion of urea during days of rest was about 32 grammes, but, during days of considerable bodily exertion, the quantity

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[1] Emilius, J. J. Rousseau, 1762.

[2] The Dialogues of Plato, particularly "The Republic," Jowett's translation.

[3] Parkes: Practical Hygiene, 1878, p. 414.

[4] Handbuch d. angew. med. Chem., 1842, 11, S. 368.

[5] Wagner's Handbuch d. Physiol. Band 11, S. 21, and Lehmann's Phys. Chemie, Bd. 1, S. 164, 1844.

rose to 36.37 grammes. W. A. Hammond (1855)[1] found that in his own case the urea was largely increased by exercise. His experiments were carried out for three days upon an uniform mixed diet. On the first day moderate exercise was taken, viz., a walk of 2½ miles and horseback ride of 3 miles; on the second day, a brisk walk of 8½ miles over a hilly country, a horseback ride of 10 miles, and 2½ hours of quoit-pitching; on the third day, absolute rest.

The following table gives the respective amounts of urea eliminated:

Moderate exercise........................	682.09 grains.
Increased "	864.97 "
No "	487.00 "

In 1861 Dr. Edward Smith conducted a series of experiments upon the prisoners at Coldbath-fields by exercising them upon the tread-wheel, and came to the following conclusions:

"1. When the tread-wheel is worked for a short period, say 1½ hours, in the absence of food, there is no increase in the elimination of urea during that period.

"2. When the tread-wheel is worked with ordinary food, the increase of urea is not more than 5 per cent. over the quantity which is eliminated with very light work and with the same food.

"3. When two different dietaries are provided, varying in nitrogen, but the exertion always remaining the same, there is the greatest excretion of urea with the diet richest in nitrogen."[2]

In 1866 Fick and Wislicenus[3] published an account of an experiment conducted upon themselves in connection with their ascent of the Faulhorn, one of the Bernese Alps, which rises 6417.5 above the Lake of Brientz. For seventeen hours before the ascent, and for six hours after its completion, no albuminoid food was taken, the diet being composed solely of cakes made of fat, sugar, and starch. At the end of this time a hearty meal of meat, etc., was eaten. The ascent began at half-past five o'clock in the morning, August 30th, and lasted eight hours. The urine was collected for three periods: (1) the eleven hours preceding the start, (2) the eight hours of ascent, and (3) the succeeding six hours of rest, the latter to allow for the elimination of any urea that might have formed, but been retained during the excretion. The amounts of urea for the three periods were respectively:

	Fick.		Wislicenus.	
1. Urea of 11 hours before labor..	238.55 grains.		221.05 grains.	
2. " " 8 " of labor......	109.45 "	189.77	103.46 "	183.35.
3. " " 6 " " rest........	80.33 "		79.89 "	

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[1] American Jour. Med. Sciences, January, 1855.

[2] Op. cit., p. 272.

[3] Philosophical Magazine, XXXI. (1866), p. 485.

The urine for the night (11 hours) succeeding the rest-period contained only (Fick) 159.15 grains of urea, and (Wislicenus) 176.71 grains, notwithstanding the hearty meal of nitrogenous food taken the evening before.

In the same year (1866), Pettenkofer and Voit, in connection with the experiments already mentioned (see p. 322), investigated the elimination of urea as affected by exercise, with the following result:

Rest-day (average of three days)	564.81	grains.
Work-day (average of two days)	567.89	"
Average deficit on work-day	3.08	"

The experiments of Fick and Wislicenus attracted much attention from their supposed important bearing upon the question of the source of muscular power, and in order to test the correctness of their conclusions, the late Dr. Parkes,[1] in December of the same year, made a series of observations upon two healthy soldiers, S. and T., belonging to the Army Hospital Corps at Netley. The experiments extended over sixteen days, two of which were occupied in moderately severe exertion, viz., a walk of 23.76 miles in one day, and another of 32.78 miles on the day following. The remainder of the time was spent either at rest or in their ordinary work. In two of the experiments the diet was restricted to non-nitrogenous substances—arrow-root, jelly, sugar, and butter. The following table gives the respective quantities of urea excreted:

I.—*Ordinary Diet and Work.*

	Grains.
Mean of 4 days—S.	540.13
" " T.	399.99

II.—*Non-nitrogenous Diet and Rest.*

Mean of 2 days—S.	258.71
" " T.	231.94

III.—*Ordinary Diet and Work.*

Mean of 4 days—S.	394.36
" " T.	330.19

IV.—*Non-nitrogenous Diet and Active Exercise.*

Mean of 2 days—S.	263.34
" " T.	225.33

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[1] Proceedings of the Royal Society, Vol. XV., 1867, No. 89, p. 339 et seq.

V.—*Ordinary Diet and Work.*

Mean of 4 days—S.	407.34
“ “ T.	359.90

These experiments demonstrate clearly that the excretion of urea is far more dependent upon the amount of nitrogen ingested than upon the energy expended by the muscles, while a comparison of the II. and IV. experiments shows that upon a non-nitrogenous diet the differences in the amount of urea eliminated were so slight as to be attributable to errors in analysis. In order to obviate the natural objection that these two experiments were conducted under abnormal physiological conditions, Dr. Parkes made another series of observations,[1] similar in all respects to the preceding experiments, except that another soldier, B., was substituted for T., that the diet was uniform (mixed nitrogenous and non-nitrogenous food) throughout the whole period, and that the distances walked during the days of extraordinary exertion were respectively 32 and 35 miles.

I.—*Ordinary Work.*

	Grains.
Mean of 4 days—S.	567.18
“ “ B.	573.05

II.—*Rest.*

Mean of 2 days—S.	591.73
“ “ B.	603.39

III.—*Ordinary Work.*

Mean of 4 days—S.	557.48
“ “ B.	579.22

IV.—*Active Exercise.*

Mean of 2 days—S.	596.37
“ “ B.	625.39

V.—*Ordinary Work.*

Mean of 4 days—S.	629.79
“ “ B.	600.44

In 1868 Prof. Haughton reported a series of experiments[2] conducted

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[1] Proceedings of the Royal Society, Vol. XVI., No. 94, 1867.

[2] The Lancet, 1868, Aug., p 261.

upon himself with reference to this point. He first ascertained by a number of observations his average elimination of urea under his ordinary conditions of exercise (walking about five miles a day), and then determined the amounts of urea excreted during five days of unusual exercise (walking on an average 20 miles daily). The result was as follows:

	Grains.
Moderate exercise	501.28 per day.
Severe exercise	501.16 "

Notwithstanding the apparently conclusive settlement of the question by the observations of Smith, Fick and Wislicenus, Pettenkofer and Voit, Parkes, and Haughton, the whole controversy was reopened in 1871 by the experiments of Austin Flint, Jr., upon the pedestrian, Edward Payson Weston, in connection with the latter's walk in New York during May, 1870, of 317½ miles in five days.[1] In 1876 Dr. Pavy conducted a series of similar observations upon the same person during his pedestrian performances in London.[2] Upon this occasion Weston undertook three separate feats: a walk of 48 hours, one of 75 hours, and a third of 500 miles in six days, the distance actually accomplished during the latter effort being 450 miles. This last walk is the only one of the three which is strictly comparable, so far as the conditions of experiments are concerned, with the one made under Flint's observation, and we have omitted the results of the first two walks from the present consideration. The general result, as given below, is not, however, materially affected thereby.

FLINT'S OBSERVATIONS.

Daily Averages for Three Periods.

	Five days before the walk.	Five days of the walk.	Five days after the walk.
Nitrogen of food	339.46 grains.	234.76 grains.	440.93 grains.
Urea	628.24 "	722.16 "	726.79 "
Uric acid	2.26 "	3.00 "	1.42 "
Nitrogen of urea and uric acid	293.93 "	338.01 "	339.64 "
Percentage of nitrogen excreted in urea and uric acid	86.58	143.98	77.03

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[1] N. Y. Medical Journal, June, 1871; also, The Source of Muscular Power, N. Y., 1878.

[2] The Lancet, 1876, Vol. I., pp. 319, 353, 392, 429, 466; Vol. II., pp. 741, 815, 848, 887.

PAVY'S OBSERVATIONS.

Daily Averages for Three Periods.

	Six days before the walk.	Six days of the walk.	Six days after the walk.
Nitrogen of food	477.48 grains.	671.72 grains.	Not calculated.
Urea	667.07 "	1089.56 "	642.30
Uric acid[1]	27.39 "	39.51 "	25.84
Nitrogen of urea and uric acid	319.91 "	521.54 "	308.30
Percentage of nitrogen excreted in urea and uric acid	66.99 "	77.64	Not calculated.

The above experiments upon Weston clearly demonstrate that with a nitrogenous diet, very severe muscular exertion, especially if continued for a series of days, unmistakably increases the elimination of urea during the period of work, over and above the amount that can be accounted for by the nitrogen ingested. With *moderate* exercise the increased elimination is often not apparent at the time, but shows itself during the succeeding period of rest. In Parke's carefully conducted experiments (see *ante*) it was found that while the excretion of urea was only slightly increased on the days of unusual exertion, a still larger amount was eliminated on the succeeding days of ordinary work. This fact possibly throws some light upon the failure of other observers to discover any increased excretion of urea, when sufficient precaution was not taken to investigate the subsequent elimination. Still this explanation will obviously not apply to other cases of failure, such as that of Prof. Haughton. In this instance the exertion was continued over a period long enough to allow any increased formation of nitrogenous products to manifest itself by increased elimination during the latter days of work. Such cases seem inexplicable if the urea eliminated during exertion or immediately afterward is to be regarded as a measure of the muscular substance consumed, but present no serious difficulty if it be considered simply as an expression of the general disassimilative changes of the body.[2]

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[1] The difference between the amounts of uric acid in Flint's and Pavy's tables is very striking, and probably depends, as Pavy has pointed out and Flint himself admits, upon the faulty process employed by the chemist to whom Flint entrusted the analysis. The error does not materially affect the general results as given by Flint. Moreover, it should be noted with respect to the percentages in Flint's table that the very marked increase during the five days' walk was due, not so much to the increase of nitrogen excreted, as to the considerable diminution in the nitrogen ingested during this period.

[2] The results of some recent experiments by William North, B.A., Cambridge, seem to point in this direction: An Account of Two Experiments Illustrating the Effects of

Source of muscular power.—These considerations bring us directly to the question of the source of muscular energy—a question which has excited more controversy of late years than perhaps any other in the entire range of physiological inquiry, and which, it is safe to say, will never be definitively settled until our knowledge of vital processes is much more complete than it is at present. The main point in dispute is whether muscular power is evolved by the consumption of the muscular substance itself, or whether a muscle is merely a machine for liberating energy from substances brought to it by the blood circulating in its tissue; whether, in the words of Fick and Wislicenus, "as in the steam-engine coal is burned in order to produce force, so in the muscular machine fats and hydrates of carbon are burned for the same purpose." For a full discussion of this question the reader is referred to the principal contributions on the subject;[1] a few general remarks must suffice here.

In the first place, it should be noted that the analogy drawn by Fick and Wislicenus between a muscle and a steam-engine is obviously misleading, if it be meant that mechanical force is generated in a similar manner in the two cases. In the steam-engine the heat liberated from coal is converted into work by means of a special mechanism, viz., the condenser, in which motion is produced by the alternate condensations and expansions of steam. No provision at all analogous to this is found in muscle. Here heat is the final product in the transformation of energy, the excretum of energy; having no cooler parts to warm, it cannot be converted into mechanical work; and the excess, above what is required to maintain the normal temperature, escapes from the body by radiation and conduction, by direct loss in the expired air, the urine, and fæces, and as latent heat in the vapor of perspiration. If, on the other hand, it be merely intended by this analogy to assert that a muscle, like a steam-engine,

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Starvation, with and without Severe Labor, on the Elimination of Urea from the Body, The Journal of Physiology, June, 1878, p. 171.

He draws the following conclusions from the observations in question:

"1. That severe exercise does increase the elimination of urea, but that the increase, both in the absence of nitrogenous food and under ordinary diet, is a small one.

"2. That the quantity of urea passed during any period is largely dependent on the nitrogenous constitution of the body for the time being, *i. e.*, varies according as a greater or smaller reserve of nitrogenous material has been accumulated in the body."

He adds: "It is quite possible that exercise may have an especial effect in hurrying on the metabolism of such a reserve, and hence, the point whether the nitrogen of the excreta is increased by exercise or not may be determined by events—not so much in the muscles as in other tissues—the result being positive or negative according as a large or small reserve is present, or according as that reserve is more or less labile."

[1] Besides the articles, already referred to, of Fick and Wislicenus, Haughton, Parkes, Flint, and Pavy, see also Frankland: On the Origin of Muscular Power, Philosoph. Magazine, London, 1866, Vol. XXXII.; Voit: Ueber die Entwickelung der Lehre von der Quelle der Muskelkraft, etc., Zeitsch. für Biologie, Bd. VI., 1870, S. 303 et seq.; Parkes: Med. Times and Gazette, 1871, p. 348; and Liebig: Pharmaceutical Journal and Transactions, London, 1870.

is a machine which evolves mechanical force, not from its own structure, but from matters brought to it for combustion, and itself undergoes no change during work except the natural wear and tear incidental to all machinery, the comparison is none the less misleading, as will appear from the following considerations.[1] It has been shown by L. Hermann[2] that a muscle, even when removed from the body, and deprived of blood by washing out the vessels with a normal alkaline solution, is still for some time capable of contraction, and of producing carbonic acid, sarcolactic acid, and heat during contraction. This fact, together with others pointing in the same direction,[3] renders it highly probable that muscular power is derived from changes in the muscular substance itself, and not from oxidation of matters in the blood circulating through the muscle. Although our knowledge is still very imperfect in regard to the nature of these changes in muscle, it is quite clear that we have to deal with a process far more complicated than a simple oxidation, such as occurs in ordinary combustion. A frog's muscle deprived of its blood contains no free or loosely combined oxygen; none can be extracted from it even under the action of a mercurial air-pump, and yet when the muscle is placed in an atmosphere of hydrogen or nitrogen, the evolution of carbonic acid, and probably lactic acid, still continues both when the muscle is contracting and when it is at rest.[4] The oxygen, on its absorption from the blood by the muscle, enters at once, it may be supposed, into the formation of a contractile substance, which even during muscular repose is always undergoing gradual disintegration, but upon the reception of the necessary stimulus splits up, by means of a sort of explosive decomposition, into carbonic acid, lactic acid, etc., and thus suddenly liberates a large amount of energy. According to this hypothesis, muscle may be regarded as a reservoir of latent force, upon which the will may at any instant draw for mechanical work to an amount limited only by certain conditions to be mentioned later. Although the products of decomposition thus far posi-

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[1] It seems to be in this latter sense that the analogy was first used by Fick and Wislicenus; at least, Fick has since explained that he does not regard the work in muscle as produced by the conversion of heat into mechanical motion, but rather by the conversion of chemical forces, possibly through the medium of electric processes. Untersuch. über Muskelarbeit, 1867, S. 43.

[2] Untersuch. über den Stoffwechsel der Muskeln, 1867.

[3] For instance, the observation that a well-nourished individual, even after entire abstinence from food for two or three days, is still capable of considerable muscular exertion. Also the following interesting fact mentioned by Liebig in his article on the Source of Muscular Power, Pharmaceutical Journal, London, 1870, p. 202: "I recently received a letter from my friend, Prof. O. N. Rood, of N. Y., in which he communicated to me the following case: Prof. Agassiz has been occupied for some time in catching sharks for the purpose of studying their anatomical structure, and on one occasion a shark, that had been hooked, struggled in the usual violent manner before it was landed; but on dissection the animal proved to be almost entirely destitute of blood. Closer examination showed that it had been attacked by a parasite, and the gills were in some places eaten through, so that nearly all the animal's blood had been extracted and its place taken by sea-water."

[4] Foster: A Text-Book of Physiology, p. 284.

tively ascertained—carbonic and lactic acids—are such as might result merely from the oxidation of non-nitrogenous material, and although there is a conspicuous absence of nitrogenous waste in the muscle during contraction, it is hardly probable that the contractile material is itself merely a non-nitrogenous body. To account for this absence of a corresponding nitrogenous waste, Hermann has advanced the theory that the contractile substance is composed of an albuminous material termed by him *inogen*, which breaks up during contraction of the muscle into carbonic acid, lactic acid, and a gelatinous nitrogenous body essentially identical with the firmly coagulated myosin found in dead muscle. This gelatinous myosin, he supposes, is retained in the muscle, and re-enters into the formation of new inogen. The theory is unsupported by direct evidence, and in fact is opposed by what is known of the origin of the myosin of rigor mortis; still the true explanation probably lies in this direction, viz., that the nitrogenous substance or substances resulting from the decomposition of the contractile material are not immediately eliminated, but are in part, at least, retained and again used in the process of reconstruction.

	Work performed in foot-tons.	Force value in foot-tons of the nitrogenous matter equivalent to the nitrogen eliminated in excess of the average during rest.
First 24 hours of Weston's six-days' walk..	1525.30	533.78
Second " " " " ..	1205.27	674.63
Third " " " " ..	1097.29	718.15
Fourth " " " " ..	1195.19	481.71
Fifth " " " " ..	1035.44	352.27
Sixth " " " " ..	967.57	397.66
Sum total for the six days................	7026.06	3158.20
Daily average..........................	1171.01	526.36

This provisional hypothesis, furthermore, furnishes a plausible explanation of the manner in which both the nitrogenous and the non-nitrogenous elements of food may take part in the evolution of muscular energy. If the nitrogenous product resulting from the decomposition of the contractile substance be retained in the muscle and re-enter into the construction of fresh explosive material, the elements which are to replace the carbonic and lactic acids eliminated will naturally be derived from the non-nitrogenous substances circulating in the blood of the muscle. Moreover, this conception of the process of contraction enables us to hold fast to the view that muscular energy springs directly from the muscle itself, without at the same time admitting that the amount of nitrogen excreted from the body during exertion over and above that eliminated during rest represents the waste of muscular tissue, and is, therefore, to be regarded as a measure of the force expended. That urea is in no sense such a guide is clearly shown by the results of Pavy's observations upon Weston. Taking the excess of urea eliminated during exercise over the quantity eliminated during rest, Pavy estimated the amount of muscular tissue which this excess might be supposed to represent, and then converted the heat that would be evolved by combustion in Frankland's calorimeter into working-power by Joule's formula. The result (see preceding page) shows that the work performed by Weston in his six-days' walk was very much greater than could be accounted for by the force-value of the muscular tissue supposed to have been wasted.

Growth of muscle.—In accordance with a general law affecting all the tissues of the body, muscle wastes during long-continued rest, and grows under the influence of exercise. Is the addition to the muscular substance made chiefly during contraction or during the succeeding period of repose? We have already seen from the experiments of Gaskell, that the increased flux of blood to the muscle begins with contraction, and continues for a short time afterward. There is reason to suppose, also, that the process of contraction itself in some way directly stimulates the organizing power of the protoplasm composing muscular fibre. It is highly probable, therefore, that the incorporation of new material, and its partial, if not complete elaboration, takes place as an immediate rather than remote effect of the functional activity of the muscle. The nature of this increase of bulk is, however, not so obvious. Does the enlargement consist of an increase in the number of muscular fibres, or of an increase in their size; in other words, to adopt Virchow's terminology, is the process a hyperplasia or a hypertrophy? Direct evidence upon this point is lacking, but there can be little doubt that the mode of growth is the same here as it has been shown to be in the development of muscle from its fœtal to its adult condition, and in the development of the uterine muscular tissue during gestation. In both these instances the individual fibres increase in size, and new fibres are also formed, probably from the connective-tissue corpuscles lying in the interspaces between the fibres.

RESULTS OF OVER-EXERTION.

The fatigue resulting from muscular exertion appears to be due to three causes: 1, Lack of contractile material for continuing the exertion; 2, accumulation within the muscle of waste products, particularly sarcolactic acid; and 3, exhaustion of the nerve-centres engaged in supplying the stimulus to contraction. The relative importance of these factors is uncertain. That even in apparently complete muscular exhaustion the loss of power is not wholly attributable to lack of contractile material is shown by the familiar fact that an energetic effort of the will may still call forth an exhibition of considerable strength. The retained effete products, moreover, seem to exert a direct inhibitory influence upon contraction; at least some experiments upon frogs point in this direction. In a frog's muscle, which has been exhausted by tetanization, irritability may be restored by washing out the waste material with a saline solution injected into the vessels; while, on the other hand, the injection of lactic acid into a fresh muscle rapidly diminishes its irritability. The third factor—exhaustion of the nerve-centres concerned in the action—plays an important part in producing certain of the symptoms of muscular fatigue ; indeed, it is quite certain that the *sensation* of fatigue which accompanies exhaustion of the muscles has its direct source in the nerve-tissue, rather than in the muscles themselves. Rest, therefore, for both muscle and nerve, is indispensable to restore the conditions necessary for contraction. Fresh contractile substance must be constructed, waste products absorbed and carried away by the blood, the normal alkalescence of the muscle restored, and a new supply of nerve-power generated. The same necessity for periods of repose exists even during the exertion itself ; intervals of relaxation are indispensable if the effort is to be continued for more than a very short time. Indeed, alternation of rest and activity, or "rhythmic nutrition," as Sir James Paget terms it, appears to be an universal law of animate nature, traceable in a great variety of vital processes, from the interrupted movements of the amœba to the larger cycles of energy seen in the diurnal recurrence of sleep—which has been aptly called, "the diastole of the cerebral beat"[1]—in the monthly intervals of menstruation in women, and in the seasonal changes in the weight of the body. Accordingly we find that those forms of exertion are particularly exhausting, in which the effort is continuous, or the intervals of relaxation are too brief ; for example, holding a weight at arm's length, or prolonged standing as compared with walking.

The *symptoms* of muscular exhaustion, besides the loss of power already mentioned, are the ill-defined sensation called *fatigue*, and, in certain cases, actual *pain*, *tremor*, or *cramp*. The tremor appears to be due to short, irregular explosions of muscular force, while cramp may be regarded as a prolonged tetanus of the muscle ; both phenomena probably depend upon an exaggeration of the normal irritability. The latter symptom is a source of great annoyance to many pedestrians, especially those in whom previous training has hardened the muscles of the thighs and legs.[2]

While muscular exercise, so long as it conforms to the law of ryhthmic nutrition, increases the bulk and effective power of the muscles, long continued over-exertion, on the other hand, tends to induce a condition of chronic exhaustion, and, in some instances, even degeneration and atrophy. These results are most frequently seen when the exertion is confined to a comparatively small group of muscles; in more general forms of exercise, prostration usually supervenes before the full extent of the damage is reached. The symptoms of chronic muscular exhaustion are of the same general character as those of acute fatigue, viz., loss of power, pain, cramps, and convulsive movements or spasms. To this special class of paralytic affections, caused by the frequent repetition of particular muscular acts, Hammond has applied the general term "anapeiratic" (Αναπειράω,

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[1] M. Foster, op. cit.

[2] The pedestrian Weston, during his walk under Austin Flint, Jr.'s observation, was noticed to be unusually free from this symptom. Flint ascribes this peculiarity to the fact that, both before and during the walk, Weston's muscles were quite soft.

to do, or attempt again), but by most writers the condition in question is variously designated according to the nature of the occupation. Thus, we have scrivener's palsy; telegrapher's, type-setter's, violinist's, pianist's, tailor's, and milker's cramp; miner's nystagmus in miners who weaken the ocular muscles by working in the dark; and hammer or hephæstic palsy in workmen whose trades involve the very frequent use of the hammer—for example, scissors-making, razor-blade striking, saw-straightening, file-forging, pen-blade forging, etc. Dr. Frank Smith,[1] to whom we are chiefly indebted for a knowledge of the latter form of palsy, has made the following estimate of the number of times the hammer is used in the daily work of the pen-blade forger: "The pen-blade forger uses a hammer about three pounds in weight. A pen-blade receives, in the process of forging and joining to the piece of iron by which it is attached to the haft, on an average, one hundred blows. The forger, if an industrious man, anxious perhaps to save, by working overtime, enough money to join a building-society or to commence business on his own account, will work twelve or thirteen hours in a day. He will make as many as twenty-four dozen blades in a day, and in so doing will deliver twenty-eight thousand eight hundred accurate strokes. The rapidity and accuracy with which these blows rain upon the slender piece of iron are wonderful to the onlooker. Supposing him to work three hundred days in the year, and to continue this for ten years, he will in that period have delivered eighty-eight million four hundred thousand strokes, and just so many discharges of nerve-force will have occurred in the motor ganglia which are engaged in the action, and in the higher ganglia which calculate the distance and judge of the amount of force necessary to be evolved."

Under the head of "Professional Muscular Atrophy,"[2] M. Onimus has described similar forms of loss of muscular power occurring in occupations which are usually quite free from this risk. One instance was that of a man employed in a draper's establishment, where his business was to replace the unfolded goods on their shelves; gradually a most remarkable atrophy of both deltoid muscles was developed. In the case of "a workman employed in a tannery, who was every day for eleven hours at work, and always felt aching and fatigued after his day's labor, there likewise supervened marked muscular atrophy, confined to certain muscles. In order to prepare the skins he had to perform with both arms a forward and backward movement, which necessitated especially the action of the muscles of the shoulder, so that these were the first to be affected, and are at present almost completely atrophied. The wasting away is almost the same in both arms, as both were in action during the man's work; whereas, in respect to the legs, the right one alone was obliged to support the whole weight of the body, and this is the only one that has wasted; it is one-half smaller than the other, and the affected muscles are those

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[1] "On Hephæstic Hemiplegia or Hammer Palsy," British Medical Journal, Oct. 31, 1874.

[2] Lancet, Jan. 22, 1876.

the action of which was the most constant, such as the rectus femoris, vastus externus, and vastus internus."[1]

Besides the above-mentioned direct results of excessive muscular exertion, there are certain injuries to the vascular system which are of sufficiently common occurrence in this connection to require mention. One of the most frequent of these disturbances is an obstinate irritability of the heart, which can sometimes be traced to organic lesions, but is often due simply to a derangement of innervation, analogous to that observed in writer's cramp and allied affections of the voluntary muscles. Of the organic lesions, some are produced suddenly as results of increased blood-pressure. Thus, a single intense effort may excite hæmoptysis, or rupture one of the valves of the heart, generally the aortic; or the inner coat of the aorta may be cracked, and the foundation laid for aneurism of the thoracic or abdominal aorta; or, finally, acute dilatation of one or both chambers of the heart may take place. The latter accident is, doubtless, rare, except when the walls have been weakened by antecedent disease; but it is quite certain, also, that acute dilatation occasionally occurs in persons whose age, habits, and general health render the existence of degeneration of the cardiac muscle very improbable.[2]

Far more frequently the damage to the heart and aorta is developed gradually through the influence of repeated overstrain. Moderate enlargement of the heart, unaccompanied by any of the lesions described below, is obviously not to be included among the pathological results in question, since in persons with whom severe exertion is habitual the cardiac muscle may naturally undergo a certain degree of enlargement which can hardly be regarded as abnormal. The earliest *morbid* effect of repeated cardiac strain, as Clifford Allbutt has shown in the article referred to above, is usually dilatation, first of the right and afterward of the left ventricle, either with or without compensatory hypertrophy. If the over-exertion be still continued, valvular and aortic lesions may ensue. In some instances the tricuspid or the mitral orifice, or perhaps both orifices, are widened by progressive dilatation of the cavities, and the corresponding valves become incompetent. Generally, however, the aortic valves are the first to suffer. Sooner or later the irritation, from repeated shocks and over-stretching, establishes chronic sclerotic changes, which thicken the valves and produce stenosis. Finally, incompetence is developed, partly by these changes, and partly by the supervention of pouching of the first portion of the aorta. Similar degenerative changes take place in the aorta itself; the elastic tissue is weakened by repeated over-distention, chronic endo-arteritis results from the continued irritation, and the walls

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[1] For a fuller consideration of this interesting class of affections, see "Writer's Cramp and Allied Affections," Ziemssen's Cyclopædia of the Practice of Medicine, Vol. XI., p. 345. It is to be noted that in many of these affections there is little or no loss of muscular power, but rather a paresis of the central nervous system, particularly of that portion which presides over the co-ordination of the muscles.

[2] See particularly the cases reported by T. Clifford Allbutt, and his own experience during an ascent of one of the Alps; St. George's Hospital Reports, 1870.

of the tube ultimately yield to the pressure, with the production of pouching, or even aneurism, if the fragile inner coat have been torn by a sudden effort.

Much scepticism has been expressed as to the possibility of these results being due to over-exertion alone, without the co-operation of other causes. Schroetter,[1] for instance, insists emphatically that over-exertion is never the sole cause of cardiac dilatation, and that hearts which are unable to meet an increased demand are for this very reason to be regarded as ababnormal—the abnormity consisting, he supposes, in some tissue-change or disturbance of innervation which cannot be recognized. It must certainly be admitted that, in many of the reported cases in which such lesions have been ascribed to over-exertion, other influences have been at work to produce tissue-degeneration, such as intemperate habits, deficiency of proper food, etc. It is equally true, also, that the natural response of the healthy cardiac muscle to a continued demand for increased work is hypertrophy, and not dilatation; still, this capacity of adaptation to the work required must have its limits in the case of the heart as well as in that of the voluntary muscles. Indeed, when we consider that in severe exertion the healthy cardiac muscle has a special obstacle to contend with, viz., the stretching of its substance by the distending force of the blood-mass, the wonder is, not that dilatation should ever occur under the circumstances, but rather that it happens so seldom. At all events, whether some morbid antecedent be indispensable or not in these cases, there can be no doubt that overstrain plays a very important, even if subordinate, rôle in the genesis of cardiac disease in persons who are habitually subjected to the consequences of excessive physical exertion.[2]

Obstinate irritability of the heart, manifesting itself in palpitation, cardiac pain and increased rapidity of pulse, has been frequently noticed in modern wars as a result of over-exertion. Dr. Da Costa[3] estimates that of all the cases of "irritable heart" reported among the northern troops during the late war of the Rebellion, about 38 per cent. were due to exhaustion induced by long or rapid marches and other forms of severe exertion. Many of the men were, to be sure, suffering at the time from diarrhœa or other debilitating affections, but in numerous instances the symptoms developed suddenly, either during or immediately after a forced march, without any evidence of previous ill-health. The same functional disorder of the heart is by no means uncommon, also, among mountain-climbers and persons who carry gymnastic or athletic exercises to excess. The more serious organic results of cardiac strain are naturally encountered most frequently among laborers whose work is of an habitually severe character, and who are at the same time exposed to other causes of tissue-

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[1] Ziemssen's Cyclopædia of the Practice of Medicine, Vol. VI., p. 201.

[2] Cf. Johannes Seitz: Zur Lehre von Ueberaustrengung des Herzens, Archiv für kl. Medic., Bd. XI. u. XII., 1873-'74; also, Ludwig Hirt: Die Krankheiten der Arbeiter, zweiter Abtheil, Aeussere Krankheiten, p. 61, Leipzig, 1878.

[3] On Irritable Heart: a Clinical Study of a Form of Functional Cardiac Disorder and its Consequences, The American Journal of Medical Sciences, January, 1871.

degeneration, intemperance, foul air, and improper diet—as, for example, coal-heavers, forgemen, longshoremen, heavy porters, miners, etc. Thus, Dr. Peacock[1] states that cardiac affections (dilatation and mitral insufficiency) are very prevalent among the workmen in some of the tin and copper mines of Cornwall, England, where the men, after working for eight hours in an impure atmosphere, have to spend an hour or more in climbing ladders to reach the surface, this effort always producing exhaustion, dyspnœa, and violent beating of the heart. In the Northumberland and Durham lead-mines, on the other hand, where the men are brought up from their work by machinery, although the air is equally impure, the miners do not suffer from heart disease more frequently than workmen above ground. According to Münzinger[2] also, the marked prevalence of hypertrophy and other cardiac affections in the neighborhood of Tübingen is to be ascribed chiefly to the practice of carrying heavy burdens up the mountains of that region. The same organic results of overstrain of the vascular system occur with special frequency in professional pedestrians, particularly long-distance runners; in fact, these persons are a proverbially unhealthy and short-lived race, and most of them ultimately break down if the profession be followed long enough to develop its full consequences. The long-distance pedestrian performances which have become so popular of late in England and this country, as well as all other exhibitions of mere endurance which involve an unnecessary and wasteful expenditure of the reserve forces that nature has wisely provided for emergencies, cannot be too severely reprobated. The whole movement is a morbid phase of athleticism, and tends to breed a class of individuals who, equally with the professional athletes of ancient Greece, deserve the reproach of Euripides, of being "useless and injurious members of the State."

It remains to be considered how far this indictment against the violation of the laws of muscular and nervous action will apply to the severe athletic exercises at present in vogue, especially boat-racing. In this country the cases of injury from rowing have not been sufficiently numerous to attract the general attention of the medical profession; but in England, where boat-racing is carried to an extent unknown with us, the subject has excited much discussion. The controversy was begun in 1867 in the London Times, by a communication from the late Mr. Skey, in which boat-racing was arraigned as a most injurious form of exercise, involving serious consequences to health either at the time or in after-life. In a subsequent communication Dr. Hope made the alarming statement that the severe exercise of boat-racing is a more effective cause of heart disease than any other with which we are acquainted, rheumatism not excepted. These serious charges called out several replies at the time, and in 1873 the whole subject of the influence of severe athletic exercises was

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[1] On Some of the Causes and Effects of Valvular Diseases of the Heart, London, 1865.

[2] Das Tübinger Herz: Ein Beitrag zur Lehre von der Ueberanstrengung des Herzens, Deutsches Archiv für klinische Medicin, XIX., 5, pp. 449 ff., 1877.

thoroughly reviewed at a session of the London Clinical Society.[1] In the same year Dr. Morgan, of Manchester, published the results of his investigations into the after-health of all the persons who had rowed in the annual Oxford-Cambridge boat-race between the years 1829 and 1869.[2] This inquiry, which involved a very extensive correspondence for nearly four years, showed that out of the entire number of contestants (294), only seventeen instances were reported in which injurious consequences were ascribed to the exertion in question. Not a single case is mentioned of that rapidly fatal form of heart disease which is occasionally seen as a result of over-exertion in the laboring classes. The details of these supposed cases of injury are too long to be given here in full; it is sufficient to say that during the entire period referred to there were only three deaths from heart disease, and nine from consumption and other affections of the chest—a small mortality compared with the average rates for the whole community. Among the survivors, one mentions an attack of chronic pneumonia of right apex following a cold caught while rowing thirty years previously; another reports himself, twenty years after graduation, as suffering from cardiac hypertrophy and dilatation; another of about the same age complains of a weak, irritable heart, which incapacitates him from ordinary employments; another mentions a purulent inflammation of the elbow-joint, caused by an accident in rowing; while three instances are reported of what appears to have been a breaking-down of the general health on passing from a very active to a sedentary life. This list of injuries, even if we admit that they were all due to the cause assigned, is certainly not a formidable one, and is probably not much larger than could be found in an equal number of men engaged in other active forms of exercise. Still, it is to be borne in mind that the contestants in the inter-university race were picked men, who had been carefully trained, and that if similar data could be obtained for the numerous college and "scratch" races, in which inferior men often take part without proper preparation, the percentage of evil results would quite likely be considerably higher. When we consider, however, the very large number of men in England, who, during a considerable portion of the year, are almost constantly engaged in boat-racing, it is surprising that so few clear cases of injury have been reported, if boat-racing were really as dangerous as the alarmists would have us suppose. At the same time it is none the less certain that boat-racing involves a severe strain upon the vascular system, and that no one can safely engage in such a contest unless he be in vigorous health at the time, and have specially prepared himself for it by careful training.

A single suggestion may be allowed, in conclusion, in regard to the regulation of the violent athletic sports at our own colleges; we say *regulation*, because, for many reasons which it is unnecessary to enumerate here, the abolition of such exercises seems undesirable. It is easy to foresee, however, from the rapidly increasing number of young men at our in-

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[1] See British Medical Journal, March 15, 1873.

[2] Op. cit.

stitutions of learning who engage in these severe sports, that the time is not far distant when reports of injury will become more numerous, unless measures are taken to diminish the danger. It is entirely feasible, at all the larger institutions at least, to place these pastimes under the general supervision of a medical officer of the college, who shall have power to examine all candidates for positions on racing crews and foot-ball teams, and to reject any one who appears to be unfitted for the place by reason of actual disease or natural delicacy of organization. The duties of such an officer should be limited to matters directly involving the question of *health*, and *other details left to the students themselves.* A responsible medical opinion, thus restricted, would undoubtedly be willingly recognized by the young men, while the college authorities, in providing such a safeguard, would perform a duty which they certainly owe, but have hitherto very generally neglected.

GYMNASTIC AND ATHLETIC EXERCISES.

Historical Sketch.

Bodily exercises, either in the form of pastimes, or as a preparation for war or for the chase, were probably practised to a greater or less extent by all the nations of antiquity. Descriptions of such exercises among the ancient Persians and Egyptians are given by Strabo, Diodorus, Herodotus, and other writers ; but systematic physical training, as a necessary part of popular education, is first met with among the Greeks. Even in the heroic age of Greek history athletic games had assumed considerable prominence. The heroes of Homer wrestle, cast the discus, and engage in foot and chariot races; but these games have not yet become a fixed institution, and the gymnasium is unknown. The remarkable development of physical culture which appears later, begins with the Dorians, a hardy race, who invade the Peloponnesus, and establish themselves in the midst of a numerous hostile population, which they are able to keep in subjection only by maintaining the most rigid discipline among themselves. In Sparta, particularly, where the odds are ten to one against the invaders, everything is subordinated to military efficiency. The training begins even in infancy. As soon as the child is able to walk, it is taught to use its limbs vigorously, and its body is hardened by light clothing and exposure. After five years of age boys are instructed in the pyrrhica, a mimic contest, with movements of defence and attack resembling those of actual combat ; and in the "anapale," a contest of wrestling and boxing. The boy is now a military pupil, and from this time onward through youth and manhood, until he is incapacitated by disease or old age, his time is spent in a constant discipline of his physical powers. Family life is unknown. The children are brought up in common, and at seven years of age the boys are enrolled in companies, mess together on a very meagre fare, and throughout life exercise twice daily in the gymnasium or on the parade-ground. In order to secure a vigorous progeny, girls and young women are subjected to a similar, though less severe training, which includes running, leaping, wrestling, and throwing the lance. The time of marriage is regulated by law, and marital intercourse allowed only under circumstances most favorable for begetting healthy children. The whole system, in short, is that of stock-breeders, and produces a degree of physical perfection that is possible only under the most careful selection and culture. "The Spartans," says Xenophon, "are the healthiest of all the Greeks, and among them are found the finest men and the handsomest women of Greece." Moreover, such a body of trained athletes are found to be invincible in war; Sparta needs no walls besides the valor of her citizens, and in time acquires such an ascendency in Greece as to dictate terms and furnish generals to her rivals.

A system capable of such results is naturally copied in many of its most important features by the Ionian States, particularly Athens; but here the training is no longer exclusively physical; the culture of the mind is added to that of the body, and the two disciplines are happily blended into what may be regarded as in many respects the most perfect system of popular education the world has ever seen. This method ultimately becomes the model for all Greece.

The Greek gymnasium, as it existed during the best period of Grecian civilization, was a unique institution. It was not merely a training-school for the young, but a resort for citizens of all ages, where philosophy, arts, and the sciences were cultivated in connection with a discipline of the bodily powers. In time the institution became universal throughout Greece and her colonies; every city had its gymnasium, or perhaps more than one, and Pausanias speaks of it as a sign by which a Greek city could always be recognized. All the appointments were of the most attractive character. The gymnasium consisted of a large square enclosed by walls, situated, when possible, near a stream to afford bathing facilities; planted with plane-trees for shade, and decorated with works of art to cultivate the sense of beauty and inspire ambition by the example of heroes. A portion of the ground was covered by a roof for protection in winter, and the larger gymnasia contained numerous buildings devoted to various purposes. Within the enclosure was room for ball-play and a running course, a stadium (606 feet) in circumference, covered with sand to make the running more difficult, and surrounded by an amphitheatre for spectators.

The exercises were very numerous, and varied somewhat in different localities: but five of them, which were called the *pentathlon*—running, leaping, wrestling, casting the discus, and hurling the lance—were everywhere practised, and formed the favorite contests at the national games. The *foot-race* appears to have been the favorite contest, the length of the short races being usually a single or double circuit of the course (200 or 400 yards), while the "long run" measured twenty stadia, a little more than two and a half miles. We have no record of the actual speed at which these races were run; indeed, the common practice of covering the track with sand would render such a record, even if we possessed one, useless for comparison with modern performances. The apparently marvellous reports of speed which have been handed down to us, such as the catching of a hare in full speed, and defeating a horse in a racing match, would certainly be more satisfactory, if we had any means for judging of the performances of the hare and the horse.

Leaping was also a very popular exercise, and was especially valued for its usefulness in military service. The broad jump was practised most frequently, and generally with the aid of weights. An inscription on a statue erected to Phaÿllos by his native city, Crotona, records a broad leap of fifty-five feet, but whether artificial aid was employed or not is not stated. The broadest running leap officially recorded in modern times was twenty-nine feet seven inches, but this was accomplished with the aid of five-pound dumb-bells, and from an elevation of four inches. Unless Phaÿllos made use of some assistance unknown to modern times, the story may safely be regarded as apocryphal.

Casting the discus has no exact parallel among athletic exercises of the present day; but the famous statue of "The Discobolus," by the Athenian sculptor Myron, supplies us with a striking representation of the attitude of the disk-thrower. The body, bent forward, and turned slightly to the right, rests upon the right leg, the left foot being raised from the ground and carried behind the right one; the left hand grasps the right thigh just above the knee in order to steady the position, while the right arm, extended almost horizontally backward, is about to make the cast. In this movement, as we know from other sources, the arm swept downward through a semicircle, and delivered the revolving disk at about an angle of 45 degrees to the horizon, the athlete springing forward at the same instant. The discus was a circular plate of stone or iron, ten or twelve inches in diameter, and sometimes perforated at the centre for the passage of a thong to aid in grasping; but usually no such assistance was used, the smooth plate being simply held in the hand, which had previously been thoroughly rubbed with dust. The weight of the discus is uncertain; probably it varied at different times and in different localities. Phaÿllos, the celebrated Crotonian athlete, to whom, as we have previously seen, a statue was erected by his fellow-citizens, was said to have cast a discus, weighing *eight* pounds, ninety-five feet. The remaining games of the pentathlon—wrestling and hurling the lance—need no special description.

Besides these and a few other exercises, such as games of ball, swimming, etc., all of which formed a part of Greek education, and were participated in by the citizens generally, there were certain contests which were gradually monopolized by a class of professional athletes, who devoted their lives to the severe training required. The most important of these contests consisted in pugilism, the *pankration*—a combination of wrestling and boxing—and the combat with the cestus, a formidable gauntlet of leather, sometimes loaded with lead or iron, which was bound to the hand and arm by thongs. During the later period of Greek history (400–300 B.C.), all the exercises of the national games fell into the hands of this professional class, and a distinction arose similar to that between the "professionals" and "amateurs" of our own day. Those who spent their time exclusively in training for, and competing in, public games for prizes, were known as athletæ (αθλα, a prize), as distinguished from the agonistai, or those who took part in the competitive exercises of the gymnasium simply for the sake of physical culture.[1] The withdrawal of the better class of citizens from the public games, and the growth of luxury in the cities of Greece, in time produced their natural results. The gymnastic art gradually disappeared from the system of public education, and the national games, although continued long after the increasing effeminacy of the people had resulted in the downfall of Greek independence, steadily degenerated into brutal combats or exhibitions of trivial feats of skill.

The careful attention paid by the Greeks to the hygienic details of exercise deserves a brief notice. As clothing was unnecessary, and even inconvenient, in the mild climate of Greece, during bodily exertion, the single garment called the ζῶσμα, a short pair of drawers, which was originally worn in the gymnasium, was after a time discarded, first by the Spartans, and afterward by all the Greeks, though at Athens complete nudity does not appear to have been the invariable rule. At the public games, contests in wrestling, boxing, and the pancration were fought by naked combatants, and after the 32d Olympiad nudity was required also of contestants in the foot-race.[2] Before exercise was begun the body of the gymnast was oiled and covered with dust and sand, partly to protect the skin from injury and from the chilliness of the air, partly to lessen perspiration, the loss of which was supposed to diminish strength, and partly to afford contestants a better hold in wrestling. After exercise in the sun, the dusty body was cleansed in a cold bath, thoroughly scraped with a strigil, and again salved with oil, the result being a firm, brown, glossy skin—a healthy tissue indicative of the general vigor of the body. The dis-

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[1] The term "athletic sports," which was adopted in England about twenty years ago to distinguish amateur from professional contests, is clearly a misnomer, so far as it is based upon Greek nomenclature. The amateur contests of the present day are "agonistic," but the former term is perhaps justifiable, as it seems to be the only one available. Its present use is a curious illustration, however, of the way in which words ultimately become distorted from their original meaning.

[2] Although the frequent contemplation of the nude male form undoubtedly favored to a very important degree the development of Greek art, the moral influence of the custom was disastrous; at least, it is very probable that the prevalence of pæderasty among the Greeks was chiefly due to this cause. The extraordinary influence which this unnatural passion exerted over cultivated as well as debased minds during the best period of Greek civilization, may be studied in The Symposium and The Laws of Plato (Jowett's translation, Vols. I., IV.); the 8th chapter of Xenophon's Symposium; the third oration of Lysias (Πρὸς Σίμωνα); Æschines' oration against Timarchus; Lucian's Amores, and the thirteenth book of Athenæus. The subject is fully treated by M. Maury: Hist. des Religions de la Grèce antique, Tome III., pp. 35–39. With regard to the purely Platonic attachments, which were also common between individuals of the male sex all through historical Greece, see J. P. Mahaffy: Social Life in Greece, London, 1874, pp. 305–312.)

pirited army of Agesilaus needed only the sight of the soft, white skins of the Persian prisoners, who had been stripped in its presence, to revive its courage and excite its derision of the foe it had needlessly feared.

As regards the preparation required of those who took part in the national games, the most remarkable feature was its thoroughness. All competitors at the Olympic games were obliged to swear that for ten months previously they had faithfully gone through all the preparatory exercises prescribed by the laws, and had practised for the last thirty days in the gymnasium at Elis. Besides the obligatory exercises, others were also employed to develop particular muscles or to strengthen the entire frame, such as carrying heavy loads, lifting heavy weights, striking at sand-bags, etc. For the education of an athlete, training was commonly begun in boyhood, and was continued without any legal limit, except in the case of uniformly unsuccessful contestants, who were debarred from further competition after thirty-five years of age, beyond which time improvement was regarded as hopeless. The training diet differed at different points. At first it was restricted to new cheese, dried figs, and wheat-bread or boiled grains; afterward meat, generally beef or pork, was allowed, but only at dinner. No restriction, however, was placed upon the amount of food, and excesses in eating appear to have been common, if we may judge from the frequent occurrence of apoplexy among the Greek athletes. The account given by Athenæus of the enormous quantity of food daily consumed by Milo—twenty pounds of meat, twenty pounds of bread, and fifteen pints of wine—is, of course, grossly exaggerated; but it is at least indirect evidence that the Greek system of training, like many of the so-called systems of the present day, was more scrupulous about the quality than about the quantity of the diet.

Among the Romans, the alliance of physical with mental culture, which characterized the Greek gymnasium in its best days, was unknown; but military gymnastics were always cultivated with much enthusiasm, until the general spirit of luxury during the later empire finally spread to the army itself, and led to the abandonment of the severe martial training which had made the Roman legions the terror of the world. These arduous exercises were shared by the officers. Marius was said never to have missed a day at the Campus Martius; and Pompey, as we are informed by Sallust, was able to compete in feats of skill and endurance with any soldier of his army. The youths of patrician families likewise practised athletic exercises—foot-races, wrestling, hurling the lance, horseback-riding, and swimming—but merely as a preparation for military service; indeed, the martial passion of the Roman nation during its long career of conquest naturally directed the practice of bodily exercises into this practical channel, rather than to competitive exhibitions such as were common in Greece. On the introduction of Greek customs, however, after the subjection of this country to Roman rule, public contests became popular, but soon degenerated into the bloody gladiatorial combats, to which the moral ruin of the nation is to be largely ascribed.

After the fall of the Roman empire, the gymnastic art gradually disappeared from civilized Europe, but was still cultivated in a rude fashion among the hardy Teutonic tribes of the north, whose warlike games had been described by Tacitus in the first century of the Christian era. The knights of the Nibelungenlied, like the Homeric heroes,

> "Hurl the stone tempestuous, and dart the whizzing spear,"

but they also engage in contests on horseback, a custom in which we can trace the origin of the tournaments of the middle ages. The women, also, as in Sparta, were inured to bodily exertion, and not only frequently accompanied their husbands upon warlike expeditions, but also, in some instances, exhibited the most daring personal bravery, as in the battle at Aquæ Sextiæ.[1] After society became organized under the feudal system, and particularly after the increase of city life, the practice of warlike games declined among the commonalty, but still survived for several centuries in the tournaments of the nobility, an institution which, Gibbon says, "impartial taste must prefer to the Olympic games of classic antiquity." Finally, the institution of chivalry itself succumbed, in turn, under the radical changes in warfare effected by the development of scientific tactics, which made infantry superior to cavalry, and by the discovery of gunpowder, which diminished the importance of individual prowess.

Although the abandonment of military gymnastics was in part compensated by the continued practice of various exercises and games, which still retained their popularity among nations of Teutonic origin, and, to a less degree, in France, Spain, and Italy, where the Germanic tribes had established themselves during a considerable period as a conquering race, the interest awakened in the institutions of ancient society by the Renaissance in time directed attention to the importance of a more systematic physical education for the young.[2] A return to Hellenic gymnastics was vigorously advocated by the German reformers Luther and Melancthon, as well as by the Swiss Zwingli, but without much practical result, except the introduction of physical exercises into a few schools and colleges established by their pupils. From time to time similar views were presented by other writers; Camerarius, of Bamberg, in his Rules of Life for Boys (about 1540); Mercurialis, a few years later, in a work, De arte gymnastica; Montaigne, in his admirable essay on The Education of Children (1580); Locke, in his Thoughts concerning Education (1693); and Jean Jacques Rousseau in his Emilius (1732), one of the seminal works of literature, to which, with all its faults, modern education owes a deep debt of gratitude. In France, Rousseau's educational theories pro-

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[1] The reader of the old German epic, "The Fall of the Nibelungers," will recall the conditions upon which "Good King Gunther" won the hand of the fierce but beautiful Scandinavian maiden, Brunhild, viz., that, at the peril of his life, he should vanquish her in hurling the spear, casting the stone, and leaping after the stone as it was thrown; also, how he succeeded only with the assistance of his noble friend Siegfried, and was again obliged to invoke the latter's services, after the marriage, to subdue the refractory bride.

[2] For an excellent account of the rise of modern gymnastics, see: An Essay on the Systematic Training of the Body, by C. H. Schaible, M.D., London, 1878.

duced a profound impression, but led to no immediate general reform, as the education of the young was at that time almost exclusively in the hands of the clergy. In Germany, however, where a movement towards greater naturalness and freedom in education was already in progress, Rousseau's ideas were enthusiastically welcomed by a few educational reformers, Basedow, Campe, Pestalozzi, and Salzmann, who introduced physical exercises into the curriculum of the schools under their charge. At Salzmann's institution, in Thuringia, gymnastics were systematically taught by the celebrated Gutsmuths, the author of several works on physical education, the last one being his Turnbuch (1818). The result of the plan adopted at this school was seen in the remarkable health of the boys, since not a single death occurred during a period of thirty-two years among the 334 pupils who had been educated there. Gymnastics never became popularized in Germany, however, until after the humiliation inflicted upon this nation by Napoleon, when a vigorous movement in favor of physical education was initiated by Frederick Ludwig Jahn, affectionately known by his countrymen as "Vater Jahn." His famous gymnasium, or Turnplatz, at Berlin, was established as early as 1811; two years afterward he left it to enter the army against Napoleon, and in 1816 returned to Berlin, where, in connection with his pupil Eisilen, he published his famous work, Deutsche Turnkunst. The importance of Jahn's services to the cause of physical education, particularly in Germany, cannot well be overestimated. He greatly enlarged and improved the hitherto imperfect system of exercises by the introduction of horizontal and parallel bars, and other new apparatus, and organized numerous gymnastic societies, or Turnvereine, which, notwithstanding their repeated suppression by the government for political causes, have done valuable work in maintaining a high standard of physical culture in Germany. In 1844 several States of the German Confederation passed decrees introducing gymnastics into all educational institutions, and central schools of gymnastics were soon afterward established for the education of teachers of the art.[1] At the same time a modified system of exercises, adapted to the requirements of military service, was adopted by the Prussian government for the training of army recruits, and this system is now employed for all the armies of the German Empire. As three years of personal service in the ranks is exacted of all able-bodied citizens after the age of twenty-one years, it will be seen that almost the entire male population of Germany enjoys the advantages of a systematic physical education at a period of life when such training cannot but be extremely valuable.

In Switzerland a similar popular movement was begun about 1815, by Clias, professor of gymnastics in the Academy of Berne.[2] Soon afterward gymnastics were introduced into the schools and colleges of the

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[1] The central gymnastic school of Prussia was established at Berlin in 1847.

[2] Clias was the author of two important works on gymnastics: Anfangsgründe der Gymnastik oder Turnkunst (1816), and Elementary Course of Gymnastic Exercises (London, 1825).

country, and were thoroughly taught at the national training-schools for teachers, so that the primary schools were kept well supplied with capable instructors of the art. Numerous gymnastic societies were organized in all the cantons, and in 1832 these societies were united into the Swiss Gymnastic Association, which held annual celebrations, and included in its membership all classes of the community. By a law passed in 1849, gymnastic exercises were made obligatory in all educational institutions.

In Denmark, a gymnasium was opened as early as 1799, by Nachtigall, through whose influence gymnastics soon became popular throughout the kingdom. The labors of Ling at about the same time, in Sweden, were less successful, though after several years' delay they were finally recognized by the government, and a Central Academy of Gymnastics was established in 1814 at Stockholm. Ling's system of free exercises was radically defective, however, in being based on a wrong conception of the true function of muscular exercise. He failed to see that the full benefits of exercise are not obtained unless the muscular contractions are sufficiently energetic to produce a decided impression upon the vascular and respiratory systems—a result very imperfectly attained by his ingenious system of mere movements of the body and limbs. His system of passive movements for invalids, however, has proved to be a valuable addition to therapeutics.

The application of gymnastic exercises to the treatment of disease had before this time been advocated in *France* by C. J. Tissot, a physician of some prominence, in a work entitled Gymnastique Médicale (1781). The introduction of the gymnastic art into that country dates, however, from the second decade of the present century, when a popular interest in the subject was awakened by Clias and Col. F. Amoros,[1] and gymnastics were gradually adopted by educational institutions, and finally by the government for the training of army recruits.[2] The French system of military gymnastics is much more elaborate than the German. While the latter consists of only a few simple movements, which are to be executed with great precision, the course of exercises for the French recruit is very extended, beginning with a series of *elementary exercises* designed to render the body supple as well as to increase muscular strength, and ending with *applied* or *practical exercises*, which are executed upon fixed apparatus, and are adapted to the professional duties of the soldier. The French system has much to commend it; but, as Maclaren[3] has pointed out, it is ill-arranged and unnecessarily elaborate. "The French," he says, "have elaborated their system to such an extent that it is difficult to say where it begins or where it ends, or to tell not what it does, but what it does not embrace. For quite apart, and in addition to, an extended range of exercises, with and without apparatus, it embraces all defensive exercises with bayonet and sword, stick, foil, fist, and foot, swimming,

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[1] The gymnasium of Grenelle, in Paris, was founded in 1818.

[2] The Central School of Gymnastics, near Vincennes, was established in 1852.

[3] A System of Physical Education: Archibald Maclaren, Oxford, 1869, p. 81.

dancing, and singing, reading, writing, and arithmetic, if not the use of the globes. The soldier is taught to throw bullets and bars of iron; he is taught to walk on stilts and on pegs of wood driven into the ground; he is taught to push, to pull, and to wrestle; and although the boxing which he is taught will never enable him to hit an adversary, he is taught manfully to hit himself, first on the right breast, then on the left, and then on both together, with both hands at once; and last, but not least, he is taught to kick himself behind, of which performance I have seen Monsieur as proud as if he were ignominiously expelling an invader from the *sol sacré* of La belle France. Now, I know of no particular reason why a soldier should not be taught all these requirements, and I know many important reasons why he should be taught some of them; but it would be difficult to assign any reason, either important or particular, why they should be called gymnastics, or be included in a system of bodily training."

In England, gymnastics have never been cultivated with the same general enthusiasm as in Germany and Switzerland, probably on account of the partiality of the English for out-door exercises. The first successful attempt to introduce German gymnastics into England was made by Clias, whose labors in Switzerland and France have already been noticed. In 1823 he was invited to England, and in the following year was appointed Teacher of Gymnastics in the Royal Military Academy at Woolwich. Through his instrumentality, gymnastics were introduced into the army and numerous educational institutions, but the interest awakened was short-lived, and after the resignation of Clias, in 1825, the movement which he had initiated gradually died out. No important revival of gymnastics took place until 1861, when a gymnastic association was formed in London by E. G. Ravenstein[1] and Roman Schweitzer, the success of which led to the formation of similar organizations in many other cities. After the Crimean war, the English government (1859) appointed a commission to examine the systems of military gymnastics used in the continental armies. The report of the commission strongly urged the adoption of some similar course of bodily training for English recruits, and measures were at once taken to carry the recommendation into practical effect. Two detachments of non-commissioned officers, under command of Colonel Hammersly, who was to superintend the new work, were sent to Oxford to be qualified as teachers by Mr. Maclaren, and, after proper training, were then removed to Aldershot, where a central school of gymnastics was established (1861) for the regular supply of instructors to the army. Gymnasia have been erected at all barracks of the British army, and the system is now in complete and very satisfactory operation. The code of instruction, which was drawn up by Mr. Maclaren,[2] is much less elaborate than the French system, while it is more thorough and practical than the

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[1] The author, in connection with Mr. John Hulley, gymnasiarch, of Liverpool, of a very excellent Handbook of Gymnastics and Athletics, London, 1867.

[2] A Military System of Gymnastic Exercises for the use of Instructors: Archibald Maclaren, Adjutant-General's Office, Horse Guards, February, 1862.

German, and is based upon the sound principle that the first requisite is to develop physical power by a simple and *gradually progressive* course of exercises, after which the practical application of this acquired power to the special duties of the soldier becomes a comparatively easy task.

From Germany gymnastics were introduced into the United States by a pupil of Jahn, Dr. Beck, who established a gymnasium in 1825, at Northampton, Massachusetts; at least this was the first gymnasium in this country, so far as we can learn, where the gymnastic art was taught by a competent instructor.[1] Although at no time very popular in this country, gymnastics have gradually gained a firm support in all the large cities, particularly in those with a large German population, while the gymnasium is now regarded as a necessary adjunct to most of the higher institutions of learning. With few exceptions, however, the gymnasia of this country are deficient in proper means for instruction. We shall have occasion to refer to this serious defect with more particularity hereafter.

In concluding this brief historical sketch a word is necessary with reference to the origin of the present system of amateur "athletic sports," which include walking, running, leaping, throwing the hammer, putting the weight, and occasionally a few other exercises. The present system has been of gradual growth, the exercises at first consisting only of feats of pedestrianism, walking and running, other events being introduced from time to time as the sports increased in popularity. Half-yearly meetings for this purpose were held as early as 1812, at the Royal Military College at Sandhurst, England; but the example was not followed at the principal English schools until about 1840, when the games were introduced at Rugby, Eton, Harrow, and several other schools and colleges. Annual meetings were established at Oxford (Exeter College) in 1852, and at Cambridge (St. John's and Emanuel Colleges) in 1855, while the University sports were inaugurated at Cambridge in 1857, and at Oxford in 1860. In 1864 was held the first annual meeting of Oxford *vs.* Cambridge, and in 1866 the annual championship meeting was founded at London, where the college champions contend with representatives from amateur organizations in all parts of the United Kingdom. In the same year was formed the celebrated London Athletic Club, which is now regarded as the chief authority upon subjects connected with athletic sports. Amateur sports as distinguished from professional contests[2] have been less

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[1] Mr. Ottignon, whose name is familiar to many of our readers in connection with the early history of gymnastics in New York, informs me that the Latin School of Salem, Massachusetts, possessed a gymnasium as early as the year 1821, but that no systematic instruction was given there. A gymnasium was established in Boston about 1825, in Tremont street, on the grounds then known as the Washington Gardens. In New York the first gymnasium was opened about 1834, by Mr Fuller, in Ann street. In 1842 another one was established by Mr. Ottignon, at the south-west corner of Broadway and Chambers street, and this was removed in 1845 to Canal street, in 1848 to 598 Broadway, and in 1849 to Crosby street, near Bleecker.

[2] In Great Britain the distinction between an amateur and a professional is rigidly enforced. An amateur athlete is defined as: "Any person who has never competed in an open competition, or for public money, or for admission money, or with professionals

popular in Scotland, and but few amateur clubs have been formed, except those connected with the Universities of Edinburgh, Glasgow, St. Andrew's, and Aberdeen, and some of the larger public schools. In 1871 the Scotch Inter-university Association was formed, and annual meetings are now held alternately at the universities composing the organization. In Ireland athletic sports have been cultivated with great enthusiasm, and with remarkable success in the record of performances. The first regular games took place at Trinity College, Dublin, in 1857, and were repeated annually thereafter; but no complete organization was effected until 1871, when the Dublin University Athletic Club was formed. The Irish Civil Service had formed an athletic club four years previous to this time. In 1872 was founded the Irish Champion Athletic Club, which is now the most prominent athletic association in Ireland, and exerts the same authority there that is wielded by the London Athletic Club in England. Numerous other clubs have been formed in all parts of the country. The athletic movement in the United States, though as yet less general than in England or Ireland, has upon the whole been very successful. The New York Athletic Club, which is now the most prominent organization in this country, was founded in 1868, established their present superior quarters at Mott Haven in 1874, and in 1876 opened annual contests for the "Amateur Championships of America," since which time the English definition of an amateur has, with a few exceptions, been strictly enforced. Athletic associations have also been formed at all the leading colleges, and inter-collegiate meetings have been held under the auspices of the "College Athletic Association" which was founded in 1875. The progress of the movement has been very rapid within the past five years, particularly in the Middle and Eastern States, and promises to extend within a short time to all parts of the country.[1]

FORMS OF EXERCISE.

Rowing.

Although the relative amount of work accomplished by the individual muscles engaged in the act of rowing varies more or less with the style of stroke, the following analysis of the muscular movements in what is known as the Oxford system will apply, with unimportant modifications, to most of the best styles of rowing at present in use for shells with sliding seats. If we begin with the position of the rower at the completion of a stroke, viz., with body erect, legs extended, arms flexed, and the oar

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for a prize, public money, or admission money; nor has ever, at any period of his life, taught or assisted in the pursuit of athletic exercises as a means of livelihood; nor is a mechanic, artisan, or laborer."

[1] An Athletic Directory, published by H. F. Wilkinson, in Modern Athletics, London, 1877, gives the addresses of 547 athletic associations which hold annual meetings in various parts of the world. The list is admittedly incomplete, but it shows very strikingly the remarkable extension of this movement.

feathered for its backward sweep, the first action is a compound one, and consists of: (1) a forward movement of the entire body along with the sliding seat, the lower limbs being at the same time fully flexed; (2) flexion of the trunk upon the lower extremities; and (3) extension of the arms to the fullest possible length. The forward sliding movement is effected by the action of the *posterior femoral* muscles aided by the *extensor* muscles of the foot; the trunk is flexed chiefly by the *psoas* and *iliacus* muscles, but in part also by the *sartorius*, *tensor vaginæ femoris* and *rectus femoris;* while the complete extension of the arms is accomplished by the *serratus magnus* and *pectoralis minor* muscles, which draw the scapulæ forward and downward toward the side of the chest, and by the *triceps* and *anconeus*, which extend the forearm. These movements involve but a trifling expenditure of force, and are merely preliminary to the effective part of the stroke, which begins as the oar-blade enters the water.

The propulsion of the blade through the water is effected by three principal movements, viz.: (1) Erection of the trunk to, or slightly beyond, the vertical position; (2) a backward movement of the entire body, produced by forcible extension of the lower extremities; and (3) retraction of the shoulder and flexion of the arms. In the Oxford system these movements are consecutive. Thus, the sliding motion does not begin until a firm hold of the water has been obtained by the erective movement of the trunk, and the arms are kept fully extended until the latter motion is completed. Whether this method has the advantages claimed for it, experience alone must decide; but it seems reasonable to suppose that the muscles will act to better advantage if they are consecutively rather than simultaneously engaged. The muscles chiefly concerned in the above movements are: (1) The *glutei*, and, to a much less degree, the *erector spinæ*, by which the trunk is raised to the erect position; (2) the *quadriceps extensor cruris* and the *flexor* muscles of the foot, by which the lower extremities are forcibly extended; and (3) the *trapezius* and the *rhomboidei*, which replace the scapulæ, the *latissimus dorsi* and the *pectoralis major*, which draw the humerus down to the side of the chest, and the *biceps* and *brachialis anticus*, by which the arms are flexed. At the completion of the stroke the oar is withdrawn from the water and feathered by a rapid extension of the wrist by means of the *extensor carpi radialis longior* and *brevior* and the *extensor carpi ulnaris.* The *abdominal muscles* are also engaged (a) in steadying the abdominal viscera against shock, (b) to a slight extent also in flexing the thorax on the pelvis, and (c) in antagonizing the action of the erector spinæ and glutei in drawing the trunk too far backward. Several small muscles are likewise engaged in the above movements.

It will be seen from this analysis of the muscular movements in rowing that the main work is done by the *glutei* and *quadriceps extensor* muscles, a subordinate part only being taken by the erector spinæ and calf-muscles, while the arms are but slightly taxed, as they are not called into action until the oar has reached a right angle with the boat—that is, not until after the most arduous portion of the stroke has been completed.

The following are the most important advantages afforded by sliding as compared with fixed seats: *increased length of stroke*, *distribution of the work among a greater number of muscles*, and *greater ease in breathing*. With the fixed seat, the trunk turns upon a fixed axis running through the hip-joints, the legs being employed merely in maintaining the axis in a stationary position; with the sliding seat, on the other hand. the axis moves with the seat and gives the rower a longer reach, thereby rendering fewer strokes necessary for the same rate of speed. A greater expenditure of force is, to be sure, required for each stroke, but this demand is met by muscles which are scarcely exercised at all with the fixed seat, viz., the powerful quadriceps extensor cruris, and, to a less degree, the flexor muscles of the foot. The chief advantage of sliding seats consists, however, in the greater ease with which respiration is carried on, as the ribs and abdomen escape the compression which attends the extreme flexion of the trunk necessary with the fixed seat.

Efficient as this style of rowing is in securing a high rate of speed, it certainly does much less to develop respiratory power than was accomplished by the old system, in which more work was done with the arms—and in a boat-race respiratory capacity is even more important than muscular power. The conditions of respiration in rowing at speed are different from those of any other form of active exercise. The breathing is regulated by the frequency of the stroke (36 to 40 and upward per minute) rather than by the demands of the system, while the complete expansion of the chest is prevented by the position of the arms. After each hurried inspiration, moreover, the breath is held during the stroke, to be followed by an equally hurried, instead of the normally gradual, expiration. Let this rapid and incomplete breathing be continued through a four-mile race, with the heart contracting violently 110 or more times a minute to supply the muscles with blood, and we have all the conditions necessary for a profound disturbance of the pulmo-cardiac equilibruim, unless the heart and lungs have been carefully trained for the unusual work. Now, *ceteris paribus*, that system of rowing will develop the greatest respiratory power which gives most vigorous employment to the muscles of the chest, as it is usually found that the dimensions of the thoracic *cavity* increase just in proportion as the muscles of the arms and chest become larger and stronger. Not that we advocate a return to heavy boats and arm-rowing, although we are satisfied that Mr. Maclaren is correct in his assertion that, while rowing has advanced as an *art*, it has deteriorated as an *exercise*;[1] still it is important that this serious defect of the modern style should be fully recognized, and corrected by the employment of other exercises to secure proper thoracic development. (See later, under "*Training*.")

As the chief strain in boat-racing falls upon the heart and lungs, the question of respiratory capacity, in the selection of a racing-crew, becomes even more important than the question of merely muscular power. Fortunately, a good muscular development is usually associated with a spacious chest and vigorous heart; but this is by no means always the case, and to neglect a careful examination upon these points is needlessly to court disaster. Among the contra-indications which should debar from a

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[1] Training in Theory and Practice: Archibald Maclaren, London, p. 16, 1874.

position on a racing-crew may be mentioned: a small girth of chest (below 36 inches), the existence of a marked family tendency to pulmonary or cardiac disease, or the previous history, in the individual himself, of any affection by which these organs may have been weakened, and *early age* in connection with rapid growth and *unusual height* of the body. The latter point deserves more careful attention than is usually given to it. Even at a mature age, very tall men are generally deficient in stamina, as has been repeatedly demonstrated by the experience of the armies of Great Britain and this country; while, below the age of twenty, it will very commonly be found that the loosely knit frames of such individuals, although sometimes presenting the appearance of great muscular strength, are incapable of prolonged excessive exertion.[1] In the case of men who have had some boating experience, the best of all tests for respiratory power is the effect of one or two sharp pulls. One of Dr. Morgan's correspondents (op. cit., p. 308) writes: "If a man can't stand a sharp practice, he can't stand a race; and I never felt any difficulty in making my selection where there was staple enough to select from. I had a good look at my man *as he got out of the boat.* If a man dropped his head and held his sides, and could not speak for a minute or two, and showed continuance of distress after the effort was over, out of the crew went he, as certain as I had charge of it. If, on arrival, he could laugh and romp, and jump high over a boat-hook, or square up for a right and left, he was 'one born to the giant,' the right sort, and no mistake; a man who would repay the trainer's trouble, and do a good eighth part of the work." With men who are unaccustomed to rowing, and to whom, therefore, the preceding test would be inapplicable, a fair estimate of the respiratory capacity may be made with Holden's siren pneumatometer, which gauges the *force* exerted by the respiratory muscles, and thus affords more reliable indications than can be obtained by the spirometer.[2]

As an *exercise*, especially for young men at an age when the frame is still flexible and capable of considerable expansion, rowing presents many advantages. It calls into action more muscles than are engaged in almost any other form of athletic exercise, and is practised under hygienic surroundings, and with a degree of pleasurable excitement that add materially to its sanitary value; while the strain upon the respiratory and circulating systems, even in boat-racing, is no greater than can be safely borne by healthy young men, if the rules of training have been carefully followed. From numerous sphygmographic observations upon the mem-

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[1] At our own universities, where boating has been long practised, selections for racing-crews are usually made with good judgment; but, at a recent important regatta, the defeated boat contained a youth *eighteen* years of age and *six feet two inches* in height!

[2] See American Journal of Medical Sciences, April, 1877: New Investigations in Respiratory Pathology, by Edgar Holden, M.D. This ingenious instrument consists of a glass cylinder, nine and a half inches long and one inch in diameter, containing a siren attached to a spiral spring. An index placed in front of the siren records the maximum power used in inspiration or expiration.

bers of an English university racing-crew, both before and after their sharp practice pulls, Dr. Fraser[1] draws the following conclusions: that the arterial tension is diminished in consequence of dilatation of the blood-vessels; that the heart propels a large stream of blood during each ventricular contraction, so as to fully distend the arterial system, notwithstanding its dilated condition; and that, finally, there is no evidence that the amount of blood propelled into the arteries during each ventricular contraction is greater than can freely pass into the veins. He adds: "It is obvious that, in the great majority of functional and organic diseases of the vascular system, the condition shown by the tracings could not possibly be maintained. The subjects of these diseases are therefore completely incapacitated from *violent* rowing exercise, and cannot be in a position to be injured by it. It is possible that the presence of incipient forms of disease of the vascular system may not altogether prevent such exercise from being undertaken; but I believe that all such diseases may be detected by the use of the sphygmograph in time to prevent further mischief."

Training.

"To the question, 'What is Training, and what is it meant to do?' I would answer," says Mr. Maclaren,[2] "it is to put the body, with extreme and exceptional care, under the influence of all the agents which promote its health and strength, in order to enable it to meet extreme and exceptional demands upon its energies." A strict adherence to this definition would, of course, obviate the objection commonly urged to a course of training, viz., that it tends to prematurely exhaust the stock of vital force, or at least to place the individual in a condition of "morbid imminence." In point of fact, however, as training is commonly practised, it too often puts the body under the influence of agents which do *not* promote its health and strength, but, on the contrary, directly tend to exhaust its energies. Nor is it surprising that this should be the case when it is considered that modern training originated with professional watermen and pugilists, who were grossly ignorant of the most elementary principles of physiology; and that although great improvements in the system of training have been made of late years, certain errors are still clung to with an obstinacy that would seem remarkable, were it not paralleled by the persistence with which many other traditional misconceptions of the laws of health retain their hold upon the popular mind. Some of these errors will engage our attention in the following very brief

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[1] The Effects of Rowing on the Circulation, as shown by Examination with the Sphygmograph, by Thomas R. Fraser, M.D., Journal of Anatomy and Physiology, Nov., 1868.

[2] Of the numerous treatises on this subject, Maclaren's work on Training (op. cit.) is by far the best, and should be in the hands of all young men engaged in athletic exercises. See also Exercise and Training: their Effects upon Health, R. J. Lee, M.D., London, 1873; Athletic Training and Health, John Harrison, M.R.C.S., London, 1869; and Dr. Morgan's University Oars (op. cit.).

discussion of our subject; at the same time it must be borne in mind that it is always difficult to regulate so delicate an organization as the human body by fixed rules, however correct they may be in their general application. For numerous details, which cannot be given here, the reader is referred to the excellent treatises already mentioned. We shall be obliged to limit our remarks chiefly to training as practised in connection with amateur boat-racing.

(a.) *Duration of Training.*—A moment's consideration of the work to be accomplished in preparing young men, who have been leading more or less sedentary lives, for the severe and long-continued exertion involved in a hotly contested boat-race, will show the importance of *time* as an element of training. Besides the necessary acquisition of dexterity in the complicated movements of the stroke, organic changes must be effected; the muscles are to be slowly built up and improved in tone, the lungs enlarged, and probably new air-cells formed, while the heart is to be educated to rapidly contract upon, and the blood-vessels to carry, an unusually large volume of blood. Moreover, these changes must be brought about *gradually*, so as at no time to overtax the organs in question. To attempt to force the process of development within the limits of a few weeks is to incur the risk of the breakdown known as "overtraining;" indeed, the danger of this result is far greater from a short course of severe training than from a properly graduated one, however prolonged.

(b.) *Reduction of weight.*—Under this general head may be considered several very common errors of training, based upon the popular belief that with most men the perfect action of the muscles is impeded by the presence of superfluous solids and water, and that to rid the body of this surplus is one of the most important objects of training. Fat, particularly, is the *bête noir* of rowing men; in the form of "internal fat" it is supposed to clog the lungs, and thus produce the "loss of wind" which is experienced on commencing training. To drive out this enemy of good breathing, running with heavy clothing is resorted to, under the impression that the fat is melted by the increased temperature of the body, and eliminated through the skin along with the copious perspiration.[1] In order to maintain the reduction in weight which is thus effected by free perspiration, the allowance of water is often restricted to the lowest possible limit. This practice is, to be sure, less common now than formerly; but by most trainers water is still regarded as a sort of necessary evil, which, to say the least, requires careful supervision. Nor is it difficult to see how the above-mentioned errors originated. The English watermen and pugilists of fifty years ago were, as a class, free livers and heavy beer-drinkers when off training, and with them the reduction of accumulated fat and fluids, by active exercise and forced perspiration, was often a necessary preliminary to putting the tissues into proper condition. Among young men of temperate habits,

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[1] The writer has been at some pains to ascertain how commonly this opinion is entertained among persons who subject themselves to courses of training, and has rarely found any one who did not regard it as an orthodox tenet of training.

however, a tendency to obesity is certainly uncommon, at least in this country, although there is frequently a small amount of subcutaneous fat, the removal of which may perhaps give freer play to the muscles. This fat is gradually removed during a course of active exercise by the natural processes of oxidation and elimination chiefly through the lungs ; but, if the training be cautiously conducted, the weight thus lost is usually nearly or quite restored by the gain in the muscles and other tissues.[1] A slight reduction of weight is effected also, at the outset of training, by the change from an ordinary diet to one still more highly nitrogenous. The experiments of Bischoff and Voit[2] on animals, and of J. Ranke[3] on man, show that, independently of exercise, the effect of an increased consumption of nitrogenous food is not only to eliminate a portion of the fat of the body, but also, for a time, to increase the discharge of water above what is taken in, the tissues thus becoming more solid and firmer in texture. While there appears to be, therefore, a natural tendency to a slight reduction of weight early in a course of training as a result of altered diet and active exercise, there is also a natural tendency to *gain* in weight, arising from the larger amount of food consumed and the increased vigor of the assimilative processes, so that any considerable permanent reduction in young men with a moderately developed panniculus adiposus may very generally be regarded as an evidence of faulty training.

(c.) As regards *water*, the only restriction needed is as to the *mode of ingestion*, since the total quantity required for each day is best regulated by the demands of the system. The sensation of thirst is a proper guide, however, only when correctly interpreted. The distressing thirst which is often experienced during and shortly after severe exercise, particularly in warm weather, arises only in part from the large loss of water through the lungs and skin (see p. 323); the main element in its production is generally a parched condition of the buccal and pharyngeal mucous membrane, induced by rapid breathing through the mouth. This purely local sensation should be first relieved by thoroughly rinsing the mouth, or by chewing a bit of lemon- or orange-peel to stimulate the secretions, and then frequent moderate draughts of water may be taken until the general thirst is entirely allayed. By this means the danger of shock to the stomach from the introduction of a large quantity of cold water is avoided, while the restoration of water to the blood and tissues is effected gradually. The same rule will apply also to the use of water during the period of exertion when the latter is long continued, as in feats of pedestrianism. Small draughts of water at such times are entirely unobjectionable, whereas copious drinking, besides being open to the above objections, tends to distend the stomach and interfere with the free action of the diaphragm. It is easy to see how the injuries which sometimes result

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[1] This remark applies only to training during cool weather. In summer most men fall off a little in weight during training, even when in good condition.

[2] Die Gesetze der Ernährung des Fleischfressers, 1860.

[3] Archiv f. Anat. etc., 1862, p. 311.

from neglect of these simple precautions should have given rise to the opinion entertained by many trainers and experienced travellers, that water is a poison during arduous physical exertion. In the French army the men when on a march are allowed to relieve thirst only by holding water or by carrying a bullet in the mouth.[1] The folly of such a practice, and the still greater folly of keeping men habitually thirsty during training, is apparent when we consider that the withdrawal of a considerable amount of water from the blood involves dehydration of the tissues, and that the muscles rapidly lose contractile power when their normal percentage of water (75 per cent.) is much reduced.[2]

(d.) *Nature and amount of exercise.*—We have already seen that while vigorous respiratory power is indispensable to the rower, rowing itself cultivates this power only imperfectly, on account of the fixed position and incomplete expansion of the chest during the exercise. To remedy this deficiency no auxiliary exercise is so useful as running. By it the lungs are freely expanded under normal conditions, and the capacity of the chest is enlarged in proportion to the growth of its contents, while at the same time muscles are called into action which are unemployed in rowing, thus securing an equal development of the muscles of the lower extremities. Upon the general value of running as an aid to rowing all authorities are agreed, but there is by no means the same unanimity with regard to its practical utility in short courses of training, or in longer courses toward the close of the training. The objection commonly urged against it in these connections is that it "takes too much out of a man," when added to the hard work done in rowing. Mr. Maclaren (op. cit.) vigorously combats this objection on the ground: (1) that the fatigue experienced after rowing is chiefly respiratory, and is therefore no test of the actual muscular work; and (2) that, in point of fact, the amount of muscular work performed in rowing at speed is by no means considerable. In evidence of the latter statement he gives the results of calculations made by Professor Haughton, of the University of Dublin, to demonstrate the force employed in the propulsion of an eight-oar boat at racing speed (one mile in seven minutes), and compares this result with the work done in walking the same distance.

The work done per man in rowing one mile at racing speed is..	18.56 foot-tons.
The work done by one of the crew weighing 158 lbs. in racing costume, walking one mile, would be........	18.62 "[3]

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[1] Parke's Practical Hygiene, 1878, p. 418.

[2] Although, as before remarked, the severe restrictions formerly practised upon this point are now very generally discarded, several instances have recently come to the writer's knowledge, which show that the old fear of water during training has not entirely disappeared from athletic circles. In one of these instances a racing-crew was kept on such a small allowance of water in warm weather, that during practice-pulls the men, while resting on their oars, would sometimes dip up the salt-water in their hands and drink it to relieve the tormenting thirst!

[3] Op. cit., p. 217.

The above comparison is clearly misleading, unless we take into account the *rate of work*, since muscular fatigue depends fully as much upon this factor as upon the amount of work accomplished, as measured by foot-tons. A mile walked at a leisurely gait hardly deserves to be called exercise, but if the speed be increased to a mile in seven minutes, the muscular exertion becomes very severe. Moreover, it is to be borne in mind that the actual racing speed for an eight-oar boat is considerably greater than that upon which the above calculation is based, and that in training for long-distance races (three to five miles) the practice-pulls involve a very considerably increased amount of exertion. Certainly the experience of the men themselves in this matter is a better guide than mathematical calculations can be, and the disinclination commonly felt for the morning run, during the period of training when the crews row twice a day, may safely be regarded as nature's warning against an excess of work. In this country, where rowing is usually impracticable during the winter months, the work of developing respiratory power by running is generally relegated to this season, the continuance of the exercise during the period of full training being left optional with the individual members of the crew. Another point of practical interest connected with the preparatory winter training deserves a moment's consideration. It being conceded that one of the chief objects of training is to concentrate power in the channel of the muscles used in rowing, how is this result best accomplished? Will the greatest effective power of the muscles be developed by a *single* exercise which simulates as closely as possible the movements of rowing, or by a number of exercises which shall give the muscles the *varied* action that nature intended for them? In other words, should the necessary work at the rowing-machines be supplemented by gymnastic or other exercises in which the same muscles are called into action in a somewhat different manner? There can hardly be any doubt, it seems to us, as to the answer to be given to this question. A certain amount of monotonous repetition of movements is of course necessary to acquire dexterity, but the more these movements can be varied the greater will be the force elicited from the muscles within a given time, and consequently the more vigorous their growth. We have briefly referred to this point because the opposite view is entertained by some trainers, who restrict the work of the winter months exclusively to running and exercise at the rowing-machines.

(e.) *Diet.*—Little requires to be said under this head, as the dietary now generally used in training differs from that of ordinary life only in the exclusion of all articles of food that are not easily digestible, and in the more liberal allowance of food, particularly of its nitrogenous elements. A word of caution, however, in regard to the *quantity* of food, may not be out of place. Fortunately the danger of over-eating is commonly averted by the good digestion that usually waits upon the "training" appetite, but the danger is not so remote as might be inferred from the little attention paid to it by trainers. The exaggerated value which is attached to animal food as a source of muscular power not very infrequently leads to indulgence in this direction far in excess of the actual demands of the body. Such excess, instead of adding to muscular power, in reality lessens it by withdrawing an unusual quantity of blood to the digestive tract, and by producing in a lesser degree the torpidity seen in the lower animals when gorged with animal food. On the other hand, over-indulgence in vegetable, particularly starchy and saccharine food, tends to induce attacks of flatulent dyspepsia, accompanied by distention of the stomach, and the "shortness of wind" so commonly ascribed to "internal fat."

As regards *alcoholic stimulants*, it is sufficient to say that the habitual use of ardent spirits during training should be absolutely forbidden, and that the milder stimulants, such as light wines and beer, even if not directly injurious, are, or at least should be, unnecessary. Depressed conditions of the body, which may seem to call for their use, are generally the result of over-training, the proper remedy for which is relaxation in the amount of work, rather than the application of a goad to the flagging powers. The English rules upon this point, which not only allow, but recommend, the moderate use of the milder stimulants, are an unsafe guide for this country. The bracing character of our climate,[1] as well as the more highly sensitive nervous organization of the American, render him much less tolerant of alcohol than his British cousin, and, therefore, much more likely to be injured by its use. We have no disposition to take extreme ground upon this question, and are perfectly willing to admit that a very moderate allowance of light wine or thoroughly fermented ale at dinner may occasionally be serviceable, particularly toward the close of training, when men are apt to fall off in condition, and yet are unable to take the relaxation which is really required. Let stimulants be reserved for such emergencies, but let it be understood at the same time that the occurrence of such an emergency, when due to avoidable causes, is evidence of a faulty training, and is a virtual confession, therefore, that the training has failed in its object of securing a perfect condition of bodily health and strength.

Still less defensible is the use of *tobacco* during training. Its influence upon the nervous system in early life is very generally depressing. Where the habit is a confirmed one, a *gradual* abandonment may be necessary to avoid undue depression; but, as a rule, less inconvenience will be experienced by an immediate discontinuance on commencing training. Good material for a racing-crew will rarely be found among those who are so addicted to tobacco as to be seriously distressed by leaving it off suddenly, while the *morale* of the crew is more easily maintained if no discrimination is allowed in favor of particular members. In long courses of training, however, the same strictness need not be observed at the outset, but a limit of time may be set beyond which entire abstinence should be insisted upon.

(f.) *Over-training.*—On some constitutions, strict training, especially

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[1] English travellers in this country very commonly experience an intolerance of the stimulants to which they are accustomed at home.

if long continued, exerts a depressing influence, manifesting itself in loss of appetite, lassitude, and often in the appearance of boils or abscesses. These symptoms are sometimes developed early in training, but most frequently toward the close of the course, when anxiety as to the result of the approaching contest, loss of sleep, and perhaps the depressing influence of hot weather, are occasionally superadded to the effects of over-exertion. Among boating men the most common situation of furuncular inflammations is upon the palms of the hands or the fundament, where the skin is subjected to the greatest amount of friction, and even a trifling irritation of these parts is liable to be developed, by continued exercise, into a diffuse inflammation which entirely disables the rower. Absolute rest of the parts, or at least a considerable diminution in the amount of work, is indispensable whenever such a result is threatened. In less serious forms of constitutional depression, the administration of tonics, with a moderate allowance of wine or Bass's ale, may be sufficient to revive appetite and restore strength; but, when these measures fail after a short trial, a few days' relaxation, especially if accompanied by a change of air and scene, will generally produce a marked improvement. Palpitation and irritable action of the heart are also of not infrequent occurrence, particularly at the outset of the training. When not due to gastric disorder, these annoying symptoms will generally be found to depend upon maladjustment of the work to the vital capacity of the heart. As we have already seen, one of the chief functions of training is to educate the vascular system to transmit, with great rapidity, a very much increased volume of blood. With a healthy heart, this process of education is unattended with risk, so long as the work is regulated according to the gradually developing power of the organ; but, when an attempt is made to force the process by unduly increasing the labor, symptoms of cardiac exhaustion, such as those described, will arise in a certain proportion of cases. A temporary reduction in the amount of exercise, and, in cases of palpitation sufficiently annoying to disturb sleep, the administration of digitalis or aconite, will usually give prompt relief.

(g.) *Cautions to be observed on abandoning training.*—The dangers to be apprehended from an incautious abandonment of "training" habits of diet and exercise are connected chiefly with the digestive and vascular systems. The temptation to indulge in indigestible articles of food, and particularly in the excessive use of tobacco and alcoholic stimulants, is frequently very strong, and, unfortunately, is not always resisted. Even when no such imprudence is committed, the same *amount* of food which was used in training is often continued after the abandonment of exercise has rendered it unnecessary, and thus the foundation is laid for digestive disorders. Again, the heart, which has been gradually educated to unusually powerful contractions, and which, in a long course of training, has undergone a certain degree of normal hypertrophy, has now to unlearn its task, and to pass through a stage of subinvolution. That this stage should be made a gradual one by continuing moderate exercise for some time after training has ceased, can scarcely be too strongly insisted upon.

Fortunately, the vascular system possesses a marvellous capacity of self-regulation, and with most men the changes in question are effected without disturbance, even when no precaution is taken. But this is not always the case; a sudden return to sedentary habits is sometimes followed for a time by a sense of oppression in the chest and violent beating of the heart, due to a failure of the organ to adjust itself to the work required of it. While we would not underestimate the harm that may be, and often is, done by injudicious training, we are entirely satisfied that a large proportion of the cases of impaired health in after-life, which are ascribed to this cause, are really the result of immoderate indulgence or of thoughtless inattention to simple hygienic rules on abandoning training.

The same necessity for careful training exists also in the case of all other competitive athletic exercises which involve an intense strain upon the vascular system. This is particularly true of running, whether in the form of racing, steeple-chasing, or in the game of "hare and hounds." Notwithstanding the greater freedom of the respiratory movements in running as compared with rowing, there is much more danger of over-strain of the heart in a sharply contested foot-race than in boat-racing, as is shown by the more frequent occurrence of faintness or actual syncope in running matches. Even sprint-races (100 to 400 yards), though less trying than long-distance courses, are not exempt from this danger, as they are generally run through from the start at full speed, while the hundred yards distance is usually finished in a single respiration. We have already pointed out the marked liability of professional pedestrians to hypertrophy and chronic dilatation of the heart. With amateur pedestrians the danger lies not so much in this direction as in the production of acute dilatation or rupture of a valve by a single intense effort, or else in the development of obstinate functional irritability by too frequent repetitions of the exercise. The best safeguard against these risks is a carefully graduated course of preparatory training.[1]

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[1] The following record of a few of the best performances in walking, running, and jumping (compiled to January 1, 1879) may be of interest:

WALKING.

By Professionals.

One mile in 6 min. 23 secs., by W. Perkins, June 1, 1874, England.

Ten miles in 1 hour 15 min. 58 secs., by W. Perkins, July 16, 1877, England.

By Amateurs.

One mile in 6 min. 44½ secs., by T. H. Armstrong, Oct. 20, 1877, New York.

Ten miles in 1 hour 26 min. 37 secs., by F. Pace, March 11, 1865, London, England.

RUNNING.

By Professionals.

100 yards in 9¼ secs., by G. Seward, U. S. America, Sept. 30, 1844, Hammersmith, England.

Before concluding our brief consideration of the dangerous side of athletic sports, a word of caution seems desirable with regard to the game of foot-ball, which has sprung into sudden popularity in this country within the past five years. Much may be said in its favor. It affords vigorous exercise to a large number of muscles, without demanding extreme exertion; it is inexpensive, and hence it is available for all classes; and furthermore, it teaches the valuable lesson of strict discipline, concerted action, and presence of mind in the midst of intense excitement. On the other hand, the game is a very rough one, and exposes the player to the risk of serious accidents. In the reign of James I. the game was regarded as so dangerous to the limbs of his Majesty's subjects that it was prohibited by law, and although the game as now played in England is much less hazardous than it was at that time, the annual list of foot-ball accidents in that country is a formidable one.[1] The American game, so far as it is at

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Half-mile in 1 min. 53½ secs., by F. Hewitt, Sep. 17, 1871, Lyttleton, Australia.

One mile in 4 min. 17¼ secs., by W. Richards and W. Lang, Aug. 19, 1865, Manchester, England.

Ten miles in 51 min. 26 secs., by L. Bennett, Cattaraugus Indian, April 3, 1863, Brompton, England.

By Amateurs.

100 yards in 10 secs., by W. C. Wilmer, Oct. 12, 1878, Mott Haven, New York.

Half-mile in 1 min. 57½ secs., by F. T. Elborough, Oct. 7, 1876, Lillie Bridge Ground, England.

One mile in 4 min. 24½ sec., by W. Slade, June 19, 1875, Lillie Bridge Ground, England.

Ten miles in 54 min. 49 secs., by J. Gibb, Nov. 17, 1877, London, England.

JUMPING.

By Professionals.

Running wide jump with dumb-bells, 29 feet 7 inches, by J. Howard, May 8, 1854, Chester Race Course, England.

Running wide jump, 23 feet 4 inches, by T. Carruthers, July, 1871, Levan, Scotland.

Standing wide jump, 13 feet 10 inches, by J. Dean, Sept. 19, 1878, Oil City, Pennsylvania.

Running high jump, 5 feet 11 inches, by E. Vardy, Aug. 27, 1859, Hayden Race Course, England.

Running high pole jump, 10 feet 10½ inches, by G. Musgrove, Aug., 1866, Cockermouth, England.

By Amateurs.

Running wide jump, 23 feet 1½ inches, by J. Lane, June 11, 1874, Dublin, Ireland.

Standing wide jump, 10 feet 5 inches, by J. J. Tickle, Sept. 2, 1871, Leigh, Manchester, England.

Running high jump, 6 feet 2½ inches, by M. J. Brooks, April 7, 1876, Lillie Bridge Ground, England.

Running high pole jump, 11 feet 1 inch, by J. E. Woodburn, July 21, 1876, Ulverstone, England.

[1] See cases of fracture, strains, periosteal swellings on the shins, concussion of the brain and spinal cord, etc., reported by Dr. Robert Farquharson, Medical Officer to Rugby School, Lancet, April 16, 1870, p. 545. Also numerous serious accidents reported in Lancet, 1875, 1876, 1877, 1878.

present systematized, is based upon the rules of the Rugby Union, which allow the ball to be picked up and run with toward the opponent's goal. This practice is forbidden by the rules of the English Foot-ball Association, and with good reason, it seems to us, for most of the serious accidents occur from a player's being violently thrown to the ground while running with the ball. Another source of danger is the "scrimmages," which play an important part in all forms of the game, and in which physical strength is allowed an undue advantage over skill. Probably no alterations can be made in the game, which would render it *entirely* harmless, without at the same time destroying its distinctive character as well as its attractiveness. In this country the game has hitherto, so far as we are aware, been unattended by any very serious accidents; but it is easy to prophesy that they will in time be the certain result of increasing rivalry, and that some important modifications, which shall at least diminish the danger, will ultimately be imperatively demanded.

GYMNASTIC EXERCISES.

As compared with out-door exercises, such as athletic sports and games, hunting, horse-back riding, etc., gymnastics labor under two disadvantages: (1) they are conducted under cover, and in winter in apartments where the artificially heated air is never absolutely pure, however perfect the ventilation; and (2) they are generally undertaken as *tasks*, and therefore lack the mental exhilaration which forms so valuable an element of recreative exercises. Without such mental stimulus, physical exercise loses most of its invigorating influence. "In mind," said Mr. Erasmus Wilson, "lies the great secret of beneficial exercise, and without it exercise is a misnomer, and a fraud on the constitution." The same idea, expressed in a less exaggerated form, is carried out at some length by Dr. Strachan in an excellent little essay on the function of *play* in the physical and intellectual development of children.[1] Still, although this spontaneous recreative element is necessarily very generally absent from systematic exercises, gymnastics are not without special advantages of their own. In a well-ordered course of gymnastics the amount of exercise may be regulated, deficiencies of development corrected, and a proportionate culture of the bodily powers secured with a greater degree of certainty, and with less danger of injurious results, than is possible with any single form of exercise. We say *well-ordered* course of gymnastics, because the gymnasium should be a *school* of physical culture, where the novice, at least, should be under the direct supervision of a competent trainer, who selects for him, not the exercises which he likes best, but those which are best for him. This educational function of the gymnasium is too often lost sight of in this country, particularly at our colleges and academies, where large sums are often expended in erecting spacious buildings filled with numerous apparatus, but without any adequate provision for proper instruction. With a few notable exceptions

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[1] What is Play? Its Bearing upon Education and Training: a Physiological Inquiry, by John Strachan, M.D., Edinburgh, 1877.

this serious fault of our gymnastic system is almost universal, and largely accounts for the absurdly disproportionate results which are obtained from the outlay of money. Spend less, if need be, upon buildings and apparatus, but provide, as the fundamental condition for the successful operation of the gymnasium, a competent instructor, who shall be responsible for the *gradual* and *proportionate* development of those under his charge, and who shall be able to inspire them with his own enthusiasm for physical culture.

THE CARE OF THE PERSON.

BY

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THE CARE OF THE PERSON.

The care of the person, viewed from a hygienic stand-point, includes chiefly those means by which cleanliness and the proper performance of the functions of the skin and its appendages are maintained, together with protection from the extremes of heat and cold and from external injury. The various additional measures employed for the purpose of preserving and increasing personal comeliness and beauty belong rather to the subject of cosmetics than to that of hygiene.

Anatomy and physiology of the skin.—The outer layer of the skin (epidermis) is composed of an innumerable number of fine horny lamellæ or scales no larger than the $\frac{1}{2500}$ inch in diameter, which are subject to constant waste and renewal, like other portions of the human body, and which are constantly being cast off in the form of a dry branny scurf. Below these and in the lower layers of the skin are thousands of minute projections called papillæ, which are the organs of common sensation, of touch, and of the sense of pain. Each one of these contains the terminal end of a nerve by means of which impressions made upon the surface are carried to the brain and spinal cord, and motor impulses, such as cause contraction or expansion of the blood-vessels or of the muscles, are sent back again to the skin. In addition, the skin contains a rich network of blood-vessels, ramifying through its tissues in all directions and, like the nerve endings, spreading over an area of nearly fifteen square feet. Beside these, the skin contains several millions of perspiratory and oil glands.

The skin may be regarded in a fourfold light: 1. *It is a protective organ.*—The skin guards the parts underneath from mechanical injury, protecting them by its bad conducting power from excessive heat and cold, and regulating the bodily temperature by the dilatation or contraction of its blood-vessels, and by the greater or less amount of perspiration which it pours forth. 2. *It is a vascular organ.*—The importance of the skin as a vascular organ is seen in the faintness produced when its capillaries are filled, and the blood drawn from the brain, as by a hot bath, and also by the dangerous congestions brought on by chilling of the surface, driving a large body of blood in upon the internal organs. 3. *It is a glandular organ.*—The number of the perspiratory glands being as great as it is, their function must be an important one. Ordinarily the perspiratory secretion does not reach the surface, but is diffused through the pulverulent layers of the skin and lost like the water of rivers flowing into the sands of the desert. This is what is called insensible perspiration, of which about two pounds are, under ordinary circumstances, secreted in twenty-four hours. Being diffused in this way its evaporation helps to equalize the bodily temperature. Under the influence of violent exercise or in the hot-air bath a large quantity of perspiratory secretion may be poured out in a very short time, showing itself in bead-like drops at the openings of the sweat-tubes, and forming what is known as sensible perspiration. The sebaceous or oil-glands are nearly as numerous as the perspiratory glands; they serve to lubricate the skin and aid in the exclusion of extraneous fluids and gases. When diseased or clogged by dirt and neglect they display black points, and on pressure their secretion can be squeezed out in the form of greasy plugs, the so-called "flesh worms," found in the face and shoulders. A certain proportion of carbonic acid is also excreted by the skin, the amount being about $\frac{1}{30}$ of that thrown off by the lungs. 4. *It is a nervous organ.*—Every impression made on the surface of our bodies is conveyed to the nerve-centres and produces its due effect, and very many mental impressions are expressed by some change in the condition and aspect of the skin. Every one has noticed instances of the former influence in the involuntary muscular movements caused by tickling the soles, and the sighing or gasping which follows when water is dashed upon the face or breast. Instances of mental impressions having their reflex in conditions of the skin are noticed in the blanching of fear, the blushing of shame, the copious perspiration of mental anxiety, and the standing on end of the hair from horror.

The constant secretion and discharge of perspiratory and oily matter upon the surface of the body, as well as the continual shedding of epidermic scales, involves a double source of defilement—from within and from without. For while these effete products are themselves constantly accumulating upon the skin, they attract, at the same time, from their oleaginous character, floating dust and dirt. If the skin is not kept clean, its glands or "pores" become clogged by these accumulations and it becomes unable to perform its functions as a glandular and respiratory organ. To promote the proper accomplishment of these functions of the skin is one of the chief objects of bathing. Another object is refreshment by the influence of the bath on the terminal nerve fibres and on the circulation of the integument, an influence which may be either soothing or stimulating, depending upon the character of the bath.

The bath.—The simplest form of the bath is that employed in the customary uses of the toilet. Those parts of the body which are most exposed to dirt, as the face, neck, arms, and hands, should be washed at least twice a day, preferably, as a general thing, in luke-warm water, and with the use of soap. Certain parts, as the feet, arm-pits, groins, and neighboring parts, should be washed every evening with the sparing use of soap. The amount of soap used in the toilet should depend upon the delicacy of the skin and the exposure to which it has been subjected. A man with a coarse, greasy skin, who has been exposed to the dust all day, naturally requires much more soap than a delicate woman whose skin is dry, and who is not much out of doors. Persons in whom the oil-glands of the skin are well developed and active, especially those about the face or shoulders, require much more soap in washing than do those whose skin is harsh, dry, and lacking in oily secretion.

It is better to apply the soap by means of the hands directly, without the intervention of sponges, wash-rags, etc. The fingers insinuate themselves more deftly into any crevice or hollow of the surface than is possible for a bit of flannel or a sponge; they can use just the requisite amount of pressure and friction, and they are not so liable to do damage in unduly rubbing or chafing the skin.

There is a good deal of choice between the various soaps which are offered in the market for toilet use. These soaps are, or should be, compounded of caustic soda and refined animal fat or the best olive-oil, with some suitable perfume. In point of fact, not only are such ingredients as rosin, cotton-seed oil, etc., made use of, but frequently rancid fats, as well as oleaginous refuse, enter into the composition of so-called "toilet soaps," strong scents being added to disguise the original evil odor. Well-known brands, as the "old brown Windsor," are thus sophisticated, and sometimes produce deleterious effects upon the skin. Opaque and mottled soaps give such opportunity for adulteration that they cannot be unqualifiedly recommended for toilet use. The best and safest soap for everyday employment is undoubtedly the pure white Castile soap of Spanish, French, or Italian manufacture. Purchased from dealers of reputation, its good quality may be depended upon, and it possesses every necessary attribute for purposes of ablution. Transparent soaps are, as a general thing, less apt to be adulterated, since they are made by dissolving "curd" soap in alcohol, and will not assume a perfect transparency unless the ingredients are of good quality. The transparent soaps made by the Pears, of London, and by Rieger, are among the best in the market, though some of American make, as the "glycerine tablet," are, so far as my experience goes, equally good. When carefully perfumed, these soaps leave nothing to be desired for practical use, and they are sufficiently luxurious for the toilet.

Cosmetics.—A few words may be said with regard to "cosmetics," properly so called. These are substances applied to the skin, hair of the head and beard, nails, and teeth to improve their appearance. None are essential to health, and some are deleterious. Numerous instances are on record of poisoning from the use of cosmetics to improve the complexion. Those which contain lead in the form of "flake white" are usually most injurious. Occasionally awkward results may occur from the use of the comparatively harmless magister of bismuth, a mixture of the nitrate and oxide, which turns black upon exposure to fumes of sulphurous acid, or even onions!

General bathing.—General bathing, aside from purposes of ablution, has for its object the promotion of the functions of the skin and the general refreshment of the body. The effects of baths are produced mainly by their action on the cutaneous nerves. The sudden immersion of the body in *cold water* causes a shock, the cutaneous capillaries contract, there is often a slight gasping, the pulse and respiration are quickened. If the water be very cold and the immersion continued, these symptoms deepen in intensity, but if the body be quickly removed from the bath, "reaction" sets in; the cutaneous vessels dilate, and there is a general sense of warmth and vigor. The effects of the cold bath being mainly due to impressions made upon the cutaneous nerves, its various modifications largely depend for their influence on their power of increased stimulating action. Extreme coldness of the water; frequent changes, as in the sea or in running streams; great force of impact, as when water falls from a height, or comes forcibly through a hose upon the body; division of the stream as in shower and needle baths, and the addition of acids or salts to the water; all appear to act by increasing the stimulating power which the water exerts upon the cutaneous nerves.

Warm baths produce an effect upon the skin directly contrary to that which is brought about by cold water: the cutaneous vessels are dilated, and the temperature is raised. While a cold bath causes a certain stiffness in the muscles if continued too long a time, a warm bath relieves stiffness and fatigue (*Lancet*).

Substances in watery solution are slightly or not at all absorbed by the skin, although gases are thus absorbed and also substances dissolved in a greasy medium. Shipwrecked sailors are able to retard the pangs of thirst by keeping their clothing saturated with water, not because the water soaks in through the skin, but because the transudation of water and its loss is thus hindered. On the other hand, in what is known as the "continuous bath," persons live day and night for months, experiencing thirst as if exposed to the air.

The simplest form of bath and that best adapted to weak and delicate individuals, is by means of the wetted sponge. The water may have any temperature desired, and a part of the body only need be exposed at any time. This bath affords a most convenient method of applying the stimulating or soothing effect of water without danger. If the water is used cold, a reaction should be induced in this, as in all cold baths. When a reaction is wanting, something is wrong, either in the condition of the individual or in the manner of giving the bath, and it should not be persisted in.

Another form of the *sponge-bath* requires the use of a large, shallow tub, in which the bather stands or sits while he receives the water from a sponge squeezed over his shoulders and against his body. The shock here is somewhat greater when cold water is used than in the first form of sponge-bath. A single affusion from the sponge is enough; the bather should then dry the body quickly. The bath should be taken in the morning on rising and in a warm room.

The *douche* consists in a stream of water, varying in size and force, applied at a greater or less distance against different parts of the body. The douche exercises a certain amount of friction and a continuous impulse on the spot to which it is applied. It quickens the circulation, and is said to favor the absorption of various diseased deposits. Its effects are so powerful that it cannot be applied for a long time continuously, but after every two or three minutes should be suspended for a short interval.

The ordinary *shower-bath* is a form of douche, the effect of which varies considerably according to the height above the head at which it is placed and the size of the apertures through which the stream pours. To obtain the most satisfactory effect—a moderate stimulation, without too great a shock—the stream should pass through a large number of very small holes, and, in this state of fine subdivision, should be poured upon the head from a very moderate height.

A variety of shower-bath—not often used, however, outside of hydropathic establishments—is the circular or needle bath, in which the bather stands within a series of rings, formed of tubes lined on the inside with holes, from which thousands of minute jets of water are projected simultaneously against every portion of the body. The stimulant effect of this bath is too great to allow of its continuance for more than a few moments in the case of most persons. Other forms of the douche, as the wave-bath, etc., are modifications of this form, without material difference in their mode of action or effect. What is known as the *Écossaise* is a douche of alternate hot and cold water. Employed in the ordinary shower-bath, which, as usually set up in most houses, can be used with hot and cold water, this form of bath is convenient and agreeable. The bather, soaping himself thoroughly, can wash off the superfluous, cutaneous, oily matter and epidermic debris under the hot shower, which opens the pores, and allows of somewhat free transudation of their secretion, and can then, by a movement of the hand, change the hot stream to a cold one, and, experiencing a momentary shock, will, an instant later, enjoy the refreshing reaction which is sure to follow. A warm bath, taken for cleansing purposes by a healthy person, should always be followed by a cold affusion; otherwise the bather runs a decided risk of catching cold, by dressing and going about while the pores, or rather the cutaneous capillaries, are in that state of dilatation and semi-paralysis, in which they are left by the warm bath.

In addition to the douche in its various forms, we may mention the half-bath, the sitz-bath, and the full-bath. The *half-bath*, in which the bather sits in a tub filled with water to the depth of from ten to twelve inches, while the upper part of the body is sponged off, is adapted to invalids in whom some chest affection forbids the exercise of pressure. For in an ordinary bath there is considerable pressure upon the surface, as much as a pound to the square inch, the influence of which on the functions of the body cannot be inconsiderable, although exactly what its effects may be has never been ascertained. The *sitz-bath* is usually taken in a tub made for the purpose, in which the hips and neighboring parts are exposed to the action of water, maintained at the desired temperature. The full or ordinary bath needs no description; its effect depends largely upon the temperature at which it is taken.

Thus far cold baths have been spoken of for the most part. Hot baths exercise a very salutary effect in many instances, depending somewhat on the degree of their heat. As ordinarily understood, the *cold bath* may be of any temperature, from below 50° F. up to 70° F. Very cold baths, below 50° F., cannot be borne long. The *tepid bath* is usually taken at 85° to 95° F. The *warm bath* may range between 96° and 104° F., while the *hot bath* is usually regarded as 102° to 110° F. Very hot baths, 110° to 120° F., are not safe; they tend to scalding, and can only be borne a very few moments, as violent action of the heart and blood-vessels sets in.

The *vapor-bath* is taken at a temperature of 96° to 110° F. There is a good deal of oppression at first and some difficulty in breathing, but soon perspiration bursts through the pores and the breathing is easy and agreeable. In the simplest form of vapor-bath the individual sits on a chair surrounded by a water-proof sheet fitting closely about the neck. Hot water is then poured over heated bricks placed conveniently under the chair. The most extensively used vapor-bath is that known as the *Russian bath.* In this bath the bather lies upon a sort of staging, the lower steps of which expose him to a moderate temperature (usually about 104° F.), while the higher ones place him in an almost unbearable heat (132° F.). Douches of hot water, copious lathering with soap, and rubbing with birch twigs and leaves are among the adjuncts of this bath. As taken by the Russians themselves in former times, flagellation, with birch twigs, was resorted to and the bather was accustomed to rush out of the bath and roll himself, all naked and steaming as he was, in the snow. Milder customs we believe prevail among the Russians of to-day, nevertheless the vapor-bath is not to be indulged in at all times and by all persons with impunity. When there is any tendency to heart disease, palpitation, etc., or fulness of the head, the vapor-bath should be indulged in with caution, or not at all.

The *Turkish bath* differs from the Russian, essentially in the fact that its atmosphere is dry, while that of the Russian bath is loaded with watery vapor. In taking a Turkish bath, the bather first enters the "frigidarium" or cooling-room, when he undresses and passes into the "tepidarium," the temperature of which ranges from 110° to 140° F. The object of this room is to bring on a gentle perspiration and to prepare the system for exposure to a still higher temperature. This is attained in the "calidarium," the temperature of which is 140° to 180° or 200° F. In this room the bather undergoes the operation of kneading or shampooing. To get the full benefit of the Turkish bath, this procedure should not be omitted; it should be performed thoroughly and gently by a skilled attendant, the hands alone being employed and rough towels, flesh-brushes, and the like entirely avoided. After sweating, shampooing, and soaping, the bather passes into the "lavatorium," or wash-room. In this room he begins with a warm shower-bath, which is gradually changed to cool, and then to cold. This not only serves to wash away the perspiration, soap, etc., but also closes the pores and causes a vigorous reaction. This last important result is always readily obtained, after passing through the hot-air bath, the feeblest persons reacting without difficulty. The bather then returns to the "frigidarium" when he dresses slowly, or, reclining wrapped in a sheet, waits the cessation of the secondary perspiration. (Jos. Wilson, M.D.) The foregoing description will apply essentially to all forms of the Turkish bath as found in this country. In our larger cities various luxurious accessories are found, which, however, do not add to the real efficiency of the bath.

The Turkish bath is one of the most efficient means of refreshment and reinvigoration we possess. Used in moderation, it is absolutely without danger, even to the delicate, and the feeling resulting from its use is one of general vigor and lightness.

While on this subject, a few words may be said with reference to the sudden shock and change of temperature brought about by the successive use of hot air and cold water. So far from being injurious to pass into water while in a state of profuse perspiration, nothing can be less harmful. On the other hand, the practice of "cooling off" before going into the water should be condemned. When the skin is in a state of excitation and the nervous powers are at their natural standard or elevated above their normal range, no danger can result from the sudden contact with cold water. It is only when the body is chilled, and the powers of the nervous system are depressed from exposure, fatigue, or disease, that any ill consequences can accrue.

Certain precautions must always be exercised in bathing of whatever sort. The bath should not be taken "on an empty stomach,"—that is, when one is conscious of being hungry,—or when one is fatigued. Nor should it follow a meal too closely; three or four hours should be permitted to elapse. Ordinarily, the proper time for bathing is in the morning, either before breakfast or about noon. A good reaction is a necessity to the advantageous use of the bath; unless the bather feels a "glow" after the bath, it has done him no good, and possibly may have done him harm. Of course this does not apply to tepid or warm baths when relaxation alone is desired. Too much bathing, especially in connection with the free use of soap, is injurious to the skin, since it is thus robbed of its oily matters, which serve to keep it smooth, soft, and supple. Every one knows how readily chapped hands are brought on in winter, and in some persons with thin dry skins in summer as well, by the use of soap and warm water, without adequate drying and cooling. As has been said above, soap is to be used, under ordinary circumstances, only upon those portions of the body which are particularly exposed to dust and dirt and when the oil-glands are active. As a general thing, the rest of the body should only occasionally be washed with the use of soap. The prolonged employment of sweating, as in the "packing" of the Water Cures, gives rise not unfrequently to the occurrence of boils and other eruptions, often stubborn and difficult to cure. Hydropathists point to these eruptions with satisfaction, as evincing the escape of "humors" from the system, but they are rather to be regarded as the unfortunate results of a debilitating treatment.

Sea-bathing is one of the most important forms of the bath. In connection with the usual accessories of fresh air and freedom from toil and care, it affords a most important aid to the preservation of health. The beneficial results derived from bathing in the open sea are chiefly due: 1. To the composition of sea-water. 2. To the shock occasioned by the action of the waves and the low temperature of the water. The effect of such baths is similar to that of the ordinary douche, only more stimulating and with the addition of the exhilarating surroundings. When sea-bathing is employed in unsuitable cases, or too often; or if, the bather remaining too long in the water, the body becomes cooled off, the stage of reaction is replaced by one of depression, local congestions occur internally, as is evinced by torpidity of the liver, imperfect digestion, throbbing headache, etc.

Bathing in the sea should not be indulged in by the very old or young; by those whose circulation is languid; by persons who have disease of the heart, chronic lung disorders, affections of the brain, or local determinations of blood. Persons in moderate health should bathe in the sea only every other day; while people of robust constitution can bathe daily. The best time to bathe in the ocean is in the middle of the morning. If, on account of the tide, or for any other reason, bathing in the early morning is indulged in, the bather should first take some light refreshment, as a cup of tea, coffee, or chocolate, and some bread and butter. On no account should sea-bathing be indulged in after a hearty meal or when fatigued. The duration of the bath must, of course, vary considerably with the individual, and also according to the time of year, temperature, state of the weather, etc. Children may stay in at first five, and later ten, minutes; women, from ten to fifteen minutes; and men, a quarter of an hour or more. This is a fair average time, and cannot generally be prolonged without vitiating the original good effect of the bath. How often one sees, in a stroll along a popular sea-beach, groups of drenched, miserable objects, with blue lips, chattering teeth, and wrinkled, clammy skin, who have been spending half a morning in alternately plunging into the waves and then walking about, dripping, in the cool air. All trace of reaction has disappeared in these too enthusiastic bathers; and they return, from what should have been an invigorating dip, in a condition approaching collapse, and often requiring the use of alcoholic stimulants to restore the system to full vitality. Such abuse of sea-bathing is, unfortunately, too common, even among those who have sought the sea-side for the improvement of impaired health.

On entering the water, the bather should immerse the whole of the body two or three times, so as to get the action of the shock from the cold water distributed over its entire surface; there should be no hesitation, no dabbling in the water, but a bold plunge should be taken at once. To repeat what was said before: it is a mistake to "cool off" before the plunge; all the warmth of the body is needed to gain a vigorous reaction. Nor is it requisite to sprinkle or pour water upon the head, wrists, etc.: this is quite unnecessary. The head ought to be uncovered and exposed to the action of the water, unless the hair is very thick and long, or for some equally valid reason. On coming out of the water, the bather should dry himself quickly with a thick, rough towel, dress rapidly, and take a brisk walk for a short distance. This is better than to pursue the practice common, at least among ladies, of retiring at once for a siesta. Should there be any feeling of exhaustion or nervous depression following the bath, a little food or drink should be taken. The cause of such depression should, however, be looked into and rectified; for if this is the usual result of the bath, either the individual is not in a condition to profit by it, or else there is something wrong in the way the bath is taken. In bathing of any sort, and particularly in sea-bathing, care must be taken to prevent the ears getting filled with water, which may give rise to much annoyance, and is said to be an occasional cause of permanent deafness.

With children, the first sea-baths should not consist in more than one or two rapid and successive immersions. Subsequent baths may be somewhat prolonged, but the child should not be allowed to remain in the water until chilled. Children should never be forced into the water, particularly into the surf, against their will. No worse preparation for a good reaction can be imagined than the condition of fright and depression existing when a terrified and screaming child is dragged, or, as I have seen, even thrown, bodily into the water by a criminally foolish parent. Regard for the little sufferer's health, not to speak of motives of the merest humanity, should prevent such cruelty.

Once in the water, the child should be encouraged to take active exercise, than which no form is more beneficial than *swimming*. This is an accomplishment which should be taught all children at as early an age as practicable. One never knows at what moment the possession of such a faculty as swimming may come into play, enabling one to preserve one's own life or to rescue another. As a means of exercise, swimming is unrivalled. In an ordinary gymnasium but one muscle or set of muscles can be brought into play at a time, but in swimming all are used in concert, and in a medium which, while permitting free play of every limb, yet offers sufficient resistance to bring out and exercise the muscular powers. In sea-bathing, we must add to this the stimulating dash of the salt waves and the delight of the pure and exhilarating atmosphere,—the most perfect combination of health-giving circumstances which can be conceived.

In cases where bathing in the open sea is inadmissible, warm sea-water baths are often valuable. Feeble persons or invalids may thus gradually accustom themselves to the use of bathing, the temperature of the water being lowered by degrees until open sea-bathing can be resorted to.

When natural sea-water is unattainable, artificial salt-water baths are sometimes employed. They are stimulant to the skin, and may be compared in their effect to those still pools on the sea-beach in which invalids and children sometimes bathe—lacking, of course, the advantage of the bracing sea-air. Their influence is largely due to the saline particles which they contain, and any solution which contains the chief constituents of sea-water will answer the purpose. Such may be made as follows:

Chloride of sodium (common salt)	9 lbs.
Crystallized sulphate of sodium	4 lbs.
Crystallized chloride of calcium	12 oz.
Crystallized chloride of magnesium	3½ lbs.

This amount is sufficient for a single bath, and is to be dissolved in thirty gallons of water. A prepared sea salt is sold in the shops, but it has no advantages over the above preparation.

Public baths.—The question of the establishment of public baths is one which should commend itself to all intelligent people, and yet it is one which in most parts of this country excites little or no interest. Every facility for proper cleanliness should be afforded the poorer, and especially the working classes, who are not only more exposed from the nature of their avocations to various sources of uncleanliness, but are also rarely so situated as to be able to cleanse themselves properly at home, much less to enjoy the luxury of a complete bath for refreshment. When our cities were small and the surrounding streams could easily be reached, personal cleanliness on the part of the working-people was not so difficult of attainment; but now, in our larger towns and cities, the lack of any, even the simplest, means of general ablution is a disgrace to our civilization. Public baths have been established recently, I believe, in Boston and New York. The latter, unfortunately, are simply floating houses moored in the slips along the river fronts, and the water with which they are supplied is filled with garbage of all kinds, and more or less tainted with sewage. Wretched as these baths are, and they have been denounced as sources of disease, the crowds which use them show the demand for some such means of refreshment. In Philadelphia a number of public bathing houses were built by the municipal authorities a few years ago, which were very highly appreciated by those for whom they were intended. The extensive river front of this city, and the comparative purity of the water permitted of these baths being placed in close proximity to the wharves; the current of the river being sufficiently strong to constantly renew the supply of water. After a season or two, however, they were given up and allowed to go to ruin—on the score of economy. At present, although Philadelphia possesses a greater number of private bath-tubs, in proportion to the population, than any large city in the world, yet, for the lowest classes, no provision for cleanliness is made, excepting by the comparatively limited efforts of some religious societies.

Many years ago Dr. Bell suggested that the waste steam of manufactories could be utilized in heating the water for public baths. He said: "Much might be done by the heads of manufacturing establishments in which steam-power is employed. It has been computed that the waste water of a 500 horse-power steam engine would suffice to furnish baths for 26,000 persons daily at an average temperature of 70° to 75° F. The water taken from the hot well of the engine, ranges from 92° to 110° F."

Clothing.—The object of clothing is chiefly the protection of the body from the extremes of heat and cold, and from the effects of sudden changes of temperature. Clothing acts mainly in virtue of its being a bad conductor of heat. In winter it keeps the body-heat from waste, in summer it prevents the absorption of heat from without. The more slowly a given material conducts heat the more efficacious is it for the purposes of clothing. Exact experiments have shown the comparative value in this respect of different stuffs. Woollen materials rank first, and with them the furs of certain animals and the down of birds; next come materials of silk and cotton, while those of linen come last. Color makes little difference with regard to heat radiated from the body. When, however, the question is of heat received, as from the sun, color makes a great difference, and material very little. For instance, when

White cotton received	100° F.
White linen received	98° F.
White flannel received	102° F.
White silk received	108° F.

Taking, however, shirtings—the same material—of different colors, the following differences were observed:

When white received	100° F.
Pale straw received	102° F.
Dark yellow received	140° F.
Light green received	155° F.
Dark green received	168° F.
Turkey red received	165° F.
Light blue received	198° F.
Black received	208° F.

This agrees with our experience. Every one knows how much hotter one feels in the sun with a black than with a white coat.

Loosely-fitting clothing, other things being equal, is warmer than tight-fitting. Clothing worn in successive layers is warmer than a single layer; two shirts worn one over the other are warmer than a single one containing the same amount of material. Clothing should be permeable to air, if it is to be either comfortable or healthy. Few people feel comfortable in india-rubber garments.

The varying facility with which different articles of clothing take up water into their interstices causes great difference in their warming properties. Water is a much better conductor of heat than air, and the frequent injury from damp clothes depends upon their rapidly conducting away the bodily heat, as well as cooling the surface by evaporation of their contained water. An atmosphere loaded with moisture in cold weather gives the greatest discomfort. Every one knows the days when it seems impossible to keep warm, and when the cold "strikes through" one. The garments under these atmospheric conditions become themselves moist, and conduct away the heat of the body more rapidly than usual. Linen readily imbibes moisture, and by condensing the products of cutaneous exhalation and allowing their evaporation, cools the skin and gives rise to chilliness. On the other hand, vestments of linen worn next to the skin are useful in a condition of excitement, soothing the irritable cutaneous surface by the coolness which they produce, as well as by the absence of fine spiculæ. Cotton-stuffs imbibe moisture much less readily than linen, and those of wool and silk are still less hygroscopic. On this account, and because of their comparatively open texture, through which vapors escape, these latter materials are slow to receive or retain the perspiration, and cool the surface less rapidly than linen. Flannel, for instance, absorbs or diffuses the perspiration and prevents too sudden changes of temperature. One may sit down on a cool bank, after violent exertion, with much less danger if dressed in a flannel-shirt than if one's dress were linen.

The non-conducting quality of clothing depends not only on its material but also upon its texture. A material of loose texture confining much air in its interstices is warmer than the same amount of clothing closely woven. Wool or cotton, carded and spread out in the shape of wadding, and enclosed in an envelope of silk, will make a warmer garment than the same quantity of material spun and woven and similarly covered. This action of clothing may be likened to that of the double window-sashes used in northern countries. It is well known how well these serve the purpose for which they are intended; but if the double-sashes could be closely joined together their united value for keeping in the heat would be scarcely greater than that of one alone. Coarseness or fineness of texture must be taken into account, as well as roughness of surface. A woollen garment, as flannel, by its innumerable points or capillary projections keeps up a continual excitement of the skin, which, in those in whom this organ is sensitive, amounts to irritation. In this respect, cotton, and, more especially, silk stuffs of looser texture, come midway between woollen and linen clothing in being less irritating than the woollen and securing more warmth than the linen.

What has been said on the subject of clothing in general, applies with peculiar force to underclothing, as coming in more immediate contact with the skin. Linen, it is safe to say, should never be worn next the skin, unless under certain circumstances, when the undue sensitiveness of the cutaneous surface renders its employment necessary. "Gauze" underwear can be procured of so light weight that there is no excuse for its abandonment even in the heat of summer. It takes up the perspiration, prevents clamminess of the skin, and guards against sudden chilling of the surface after profuse perspiration. Knit underclothing is the proper wear for most persons during the greater part of the year. Delicate individuals may, however, preferably wear flannel, if the skin is not too sensitive.

The flannel used in underclothing should not be of too fine quality, nor of too close texture, or free transpiration may be hindered. It should not be worn when it chafes and reddens the skin. While due changes in weight and thickness of underclothing may be made in accordance with the changing seasons, care must be taken that these are not premature. It is better to suffer from an excess of clothing, than to change rashly and run the risk of contracting disease.

Too little attention is paid to the shape and form of clothing, with reference to its influence upon the general health. It would seem hardly necessary to say that no part of the body should be so limited and compressed by the clothing as that the due performance of its functions should be interfered with. But, unfortunately, the dictates of fashion, or the promptings of vanity, lead many to wear clothing of such a shape as almost inevitably to give rise to disease or deformity. Perhaps the most pernicious article of dress in common use among women is the corset, a garment which, in spite of the removal of some of its worst features, is still the prolific cause of numerous ills. I shall not waste words in railing against the corset; indeed I am prepared to admit that as a support, in the case of obese persons, it may be of use. But when the corset is worn tightly laced, it presses downward all the abdominal viscera, confines the play of the thorax, and interferes greatly with the movements of the diaphragm, injuring the organs of digestion, respiration, and circulation. Among men the support of the clothing by means of straps or belts is likely to give rise to trouble. "Bracing up," by buckling a belt tightly about the waist, as practised by school-boys about to use violent exercise, is an unsafe procedure, and is calculated to promote the occurrence of rupture. The pressure of a tight cravat is injurious, as also that of a tight garter, which is sure sooner or later to give rise to varicose veins of the leg. The full, flowing, and long skirts often worn by women, even in the streets, the whole weight of which is suspended from the waist, are pernicious and extremely uncleanly. The bearers of these trains move under an encumbering load, which renders proper exercise for the limbs impossible; and even when the skirts are carried in the hand, they are embarrassing. In addition, it would seem incredible, if it were not so frequently observed, that delicate, and in most respects fastidious, women should permit their clothing to sweep along and gather up the filth and garbage of the public streets.

There are certain dye-stuffs used in coloring clothing which give rise to irritation and at times to disease of the skin. Such are the various shades of red derived from aniline, which are used in dying stockings and sometimes other underclothing. Numerous cases of poisoning from garments thus dyed have been recorded in the medical journals during the past few years. Some of the dyes used in coloring leather are likewise irritating to the skin. A case came under my notice a few years ago in which a band of blisters around the ankle occurred in a young woman who had worn for a few days a pair of shoes lined with yellow leather. The action of the perspiration seems to arouse the poisonous qualities of the dye, and such garments may be worn with impunity if not in immediate contact with the skin.[1]

Fabrics, the texture of which is coarse and the surface rough, may prove irritating to a high degree. The popularity enjoyed by red flannel as a covering in various ailments is dependent in no small measure on the stimulant effects, upon the skin, of its rough surface; its color goes for little or nothing. Eruptions are not unfrequently caused upon delicate skins by the contact of irritating underclothing. Chafing between the thighs is often due to the irritation of woollen materials, together with the saline particles from evaporated perspiration. Bathers at the sea-shore, whose coarse flannel suits become saturated with sea-water, are apt to find great irritation result from even a little exercise on the beach; the threads of the rough flannel rapidly become crusted with fine spiculæ of crystalline salt, which cut into the skin with a thousand microscopic edges at every step. Many a case of so-called "poisoning" of the skin from hired bathing-clothes is nothing more than an intense irritation of the surface by this rough clothing. To prevent such irritation, a pair of cotton swimming-drawers may be worn; but it may occur, under the conditions mentioned, just as well in using private as public bathing suits.

There is some difference of opinion as to the change of clothing necessary at night; and this may safely be left to individual taste and experience. It is generally agreed, however, that the clothing worn at night should be loose, easy-fitting, and light. To this end the bed-room should not be too cold. There is a widespread delusion among otherwise intelligent people to the effect that cold air is necessarily fresh air. But this is far from true; a bed-room into which a gentle current of fresh and warmed air has been passing the night long is much more likely to be free from foul air in the morning than the same room with all heat turned off and hermetically closed. There is also much less danger of catching cold in a slightly-warmed bed-room while dressing and undressing. If the atmosphere of the bed-room is too cold, an extra quantity of covering must be placed upon the bed, tending to impede the free breathing of the sleeper, and to prevent, to some extent, ready transpiration from the skin. Many persons who wear woollen material next the skin through the day are accustomed to substitute linen or cot-

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[1] The following bill was introduced into the New York legislature during its last session:

SECTION 1. Any person who shall manufacture for sale, or who shall knowingly sell or permit to be sold by another for his benefit any poisoned or poisonous goods or garments injurious or dangerous to health, shall, for every such offence, be adjudged guilty of a misdemeanor.

SEC. 2. Any person injured by or in consequence of poisoned or poisonous goods or garments, shall have a right of action against the person or persons, firm, association, or corporate body, by or for whom such goods or garments were manufactured or sold, for all damages sustained, and for exemplary damages.

SEC. 3. On the trial of any action authorized by this act, proof of the manufacture or sale of poisoned or poisonous goods or garments shall be presumptive evidence of knowledge by the party prosecuted of such poisoned or poisonous condition.

ton underclothing at night. I think this unadvisable, as the change is too great. The same underclothing should not be worn day and night. A fresh garment should be worn next the skin while in bed; and the day garment, if not cast off as soiled, should be thoroughly aired through the night. The night-gown, or bed-gown, should be preferably made of cotton, loose, especially about the neck, and, in winter, quite long, as the feet and legs demand special protection from cold during the night.

Beds.—The subject of beds and bedding demand more attention than is usually given them. We spend about one-third of every twenty-four hours in bed; and the conditions connected with perfect and healthy repose should be the object of serious consideration.

In this country the bedstead is usually of wood, more rarely of metal. A wrought-iron or brass bedstead, of thoroughly good construction, is perhaps the best for general use: it is lighter and more easily handled, and is not so likely to harbor dust or vermin. It should be placed upon easily rolling castors, in order that it may readily be moved about and exposed to the air; for it is an ordinary experience of housekeepers that clumsy and heavy pieces of furniture are not cared for and kept clean as they should be by servants. No articles, of whatever kind, should be kept under the bed. To prevent this, it is a good plan to tuck in the bedclothes, or at least not to let them hang down too near the floor. The old-fashioned "valence," which has recently begun to come into use again, is to be condemned, in spite of its neat appearance, as favoring the concealment of odds and ends beneath the bed. Bed-curtains have also recently again come into limited employment, but are ordinarily put up rather with a view to picturesqueness than for comfort's sake. They were formerly employed to protect the sleeper from cold currents of air; but in a comfortable, modern bed-room they are mere worthless dirt-catchers, lacking, however fine in material or adornment, the first essential of beauty in furniture—usefulness. Bed-curtains of woollen or silken stuffs may also afford, on occasion, a resting-place for germs of infection.

The matrass should be made of elastic material, not giving way too easily and sinking into hollows in places, but supporting the body at all points. For the very young and old, matrasses should be made of warmer materials than for those of middle age. The materials ordinarily used for matrasses, stated in the order of their increasing power for retaining the warmth of the body, are as follows: 1. Straw. 2. Corn-husks, or palm-fibres. 3. Paper shavings. 4. Sea-moss, or Florida-moss. 5. Cotton-flock. 6. Hair. 7. Wool. 8. Feathers. 9. Down.

Formerly the matrass was simply a bag of feathers, and later was made of corn-husks, straw, etc. At the present day, however, the hair matrass is most widely used, and, when attainable, is to be preferred above other kinds. It should be made of the best black horsehair, carefully steamed (lest it should harbor a minute moth, which is said to infest the natural hair), and curled. The elasticity of the hair matrass is remarkably persistent, and it may be re-steamed and twisted from time to time, lasting a number of years. The hair matrass is not too warm for ordinary use: it does not provoke perspiration, as the feather matrass does, often to an uncomfortable degree. On the other hand, it is sufficiently warm even for old persons, excepting in cold weather, when a down comforter can be laid over it. Sometimes a quantity of inferior material, as husk, is covered with a layer of hair, making a reasonably comfortable matrass, and formerly it was the custom to place a husk, straw, or sponge, matrass upon the bed-frame and to lay the hair matrass upon that. Of late years spring matrasses have been substituted, the frame containing the springs fitting to the bedstead, and the hair matrass lying directly upon it. Of the great variety of spring matrasses in the market, two have proved pre-eminently satisfactory. One of these is known as the "Tucker matrass." It is composed of a frame containing longitudinal slats which are supported at each end by springs. The weight of the body is so evenly distributed, that it never causes an undue strain upon any single spring, and, consequently, these matrasses are very durable. They can, moreover, be easily repaired, and any worn-out spring can be replaced. The "woven wire matrass," when of the best make, is perhaps as nearly perfect as any form of spring matrass yet devised. It is composed of galvanized wire, "woven" into an open-work sheet, but with the wires of each mesh curved, so as to give an innumerable number of small and very elastic springs. It has been complained of these matrasses that they are liable to sag under the weight of heavy people; but I am informed by trustworthy persons that, when made of the best material, they are very durable, and they are certainly very luxurious. A very cool bed for the summer season may be made by covering the woven wire with a coverlet or very thin hair matrass.

Pillows are variously made of feathers, hair, sponge, etc.; occasionally rubber air-pillows are employed. Many persons cannot sleep on feather pillows, either because they heat the head unduly, or because of some constitutional irritability of the air-passages, giving rise to asthma from the emanations of the feathers. Hair pillows are very suitable for such persons, and also for children whose heads perspire readily.

The proper and usual material for sheets and pillow-cases is linen. Cotton is only appropriate in the case of persons so easily chilled as to feel cold between linen sheets.

Blankets should be all-wool and of the best quality. On the principle stated above, several thin blankets are warmer than a single thicker one of equal weight. The eider-down coverlet is one of the warmest and at the same time the lightest of all coverings; its effects are insidious, however, and in the case of invalids should be watched; it is apt to throw the sleeper into a violent perspiration. The old-fashioned coverlet of quilted cotton, which is still a favorite bed-covering in country districts, is one of the worst which can be imagined; it combines the maximum of weight with the minimum of warmth.

Beds should be carefully aired, daily. This may seem to some an unnecessary piece of advice, yet it is far otherwise, for if this part of household work be left to servants it is not likely to be well attended to. Each covering of a bed which has been slept in should be removed, the matrass doubled over, the pillows beaten, and the whole of the bed gear exposed to fresh air for at least an hour every morning. Otherwise the effluvia thrown off by the body through the night cannot properly be removed.

The feet.—Among the different parts of the person requiring especial mention with reference to their care, the feet are perhaps the most important. No portion of the body is more abused and neglected, and few parts have suffered more woefully at the bidding of fashion and vanity. Composed, as the foot is, of a delicate but wonderfully firm and elastic tissue of bones and tendons arranged in the form of an arch, so as best to support the weight and to distribute the shock of jumping, walking, etc., it is evident that the less its movements are hampered the more graceful must be the carriage of the individual and the less the danger of deformity and disease. If a healthy foot is planted firmly upon the ground, it will be seen that the great toe lies in a line with the inside of the foot, while the others lie evenly in a row, each one barely touching its neighbor, and the outline of the whole member as different from that of an ordinary shoe as can be imagined. It is not too much to say that in the "neatly-fitting" shoe, as ordinarily worn, one or more of the toes—and usually several—must of necessity *ride* the others. As a result, we have not only corns and bunions, but occasionally the most grotesque deformities. To preserve the natural shape of the foot as nearly as possible, the shoe must be rightly shaped—that is, in accordance with the proper outline of the foot,—it must fit closely, neither tightly nor loosely, and it must be made of pliable and soft leather. In addition, the feet must receive regular care; they must be bathed frequently, the nails kept well trimmed, and any abnormally thick skin scraped away to prevent the formation of callosities. Shoes made upon what is called the "Waukenphast" model are the best and most perfectly devised, with reference to their adaptability to the natural shape of the foot, of any at present made. They can now be procured of shoemakers in all our large cities, and are very generally worn by those intelligent members of the community, both men and women, to whom comfort and appropriateness are the first requisite in matters of dress. Closely connected with the shape of the shoe itself is that of the heel. This is almost invariably too small, usually too high and not unfrequently misplaced. The size of the heel may vary somewhat according to the weight of the individual; for men it should be very nearly as large as the ball of the heel itself. It should not be more than three-fourths of an inch high and should be placed well back. In women's shoes the heel is almost always too small and invariably placed too far forward. When the heel is too high the foot is pressed forward by the weight of the body, and the toes are forcibly compressed into the funnel-shaped point of the shoe, the nails are driven backward or curved out of shape, and the severe malady known as ingrown toe-nail is not seldom the result. Heels placed too far forward break the spring of the pedal-arch, and, as if one placed a block of wood under the spring of a carriage, every jolt is transmitted without any mitigation to the whole frame.

With high heels, the strain on the ankle-joint of any slight deviation from the perpendicular is felt much more strongly, and there is a tendency to easily sprain the ankle. The gait of a person wearing high-heeled shoes is tottering and ungainly, as may be noticed even at a distance and by the unpractised eye.

Shoes should not be made of hard or unyielding material, but of the softest and most pliable which can be obtained. The sole should not be very thick, as this prevents due bending in walking and tires the pedestrian unconsciously. The best form of shoe is the tie; elastic gaiters, though convenient, can never, after the first few times of wearing, fit snugly. High boots are inadmissible ; they comprise a quantity of useless leather, which keeps the leg in a perspiration and prevents due ventilation about the foot. They never can be made to fit closely around the ankle and instep without being too tight. They are apt to chafe the heel. Ready-made shoes are an abomination, and should never be worn. The small economy in purchasing such shoes is more than counterbalanced by the discomfort and injury which they inflict. A well-made shoe should fit so comfortably that it may be worn continuously from the time it is first put on. To "break in" a pair of ill-fitting shoes at the expense of the feet is to voluntarily repeat the cruelties of fabled Procrustes upon one's own flesh and blood. The best form of shoe for every-day use is that known as the "Balmoral," which covers the ankle-joint and fits snugly, in consequence of the strings with which the pressure can everywhere be regulated and equalized. Those parts of the foot which need full play are thus allowed to move freely, while about the ankle, where the tendons lie close to the bone, the shoe can be securely fastened. Children are sometimes caused to wear their shoes on alternate feet, with the view of preventing running down at the heel. This custom is extremely pernicious. Shoes should not be allowed to wear down on one side or the other without being reinforced in good time. This tendency to wear down on one side is usually in proportion to the height of the heel; sometimes it appears to be due to some peculiarity of shape in the foot itself. A skilful shoemaker can often obviate this by altering slightly the shape of the shoe.

Ill-shaped stockings sometimes aid in deforming the feet. The stocking, while it should not be so large as to lie in wrinkles over the foot and chafe it in walking, should be long and wide enough to give the toes full play. Most stockings are pointed at the toe, and are for this reason ill-shaped. Stockings are sometimes woven larger at the toes than usual: such are to be preferred when they can be procured. A stocking divided for the toes, or at least for the great toe, has often been suggested, and has indeed been worn; it would seem to be a salutary shape.

A sheet of india-rubber is sometimes placed between the layers of leather in the soles of shoes in order to aid in keeping the feet dry. Occasionally felt or cork-soles are placed within the shoe with the same object. There is no objection to the use of these if they do not supplant the rubber overshoe, which should always be worn in wet weather, and especially in the snow. Too often ladies go without overshoes in damp and wet weather, relying on the thickness of the soles of their shoes, and exposing themselves to unnecessary risk in order to avoid the cramping feeling given by overshoes, and to preserve the neat appearance of the feet.

The proper care of the feet demands that, under ordinary circumstances and with the usual conveniences at hand, they should be bathed every evening in cool water before retiring This is the more essential in hot weather or when the feet tend to undue perspiration. In the latter case alcohol and cold water should be employed. Hot water and soap should not be used when excessive perspiration of the feet exists, as they tend to aggravate the condition. When a foot-bath cannot be obtained, the feet may be rubbed off with a little acidulated or astringent water. Even dry frictions with a soft towel are of use in removing the accumulated perspiratory matter and effete scarf skin. The toe-nails should be cut regularly and carefully, otherwise they are pressed upon by the shoe and may become distorted or grow under the skin surrounding them. The skin about the toe-nails should be carefully pressed back from time to time, or it is apt to become stretched and tear. When callous patches begin to form on any part of the foot, they should be taken in hand at once. If the shoe presses or rubs at that point it should be enlarged or changed, and the foot being well soaked in warm water, the callosities should be rasped with a file or scraped with a dull knife every evening until they are removed. Corns and bunions should not form when properly shaped shoes are worn. When corns do occur, the same method of removing them should be practised as in the case of callosities, or, if they are inveterate, the services of a competent chiropodist should be sought. Repeated soaking and scraping, relief from pressure by diachylon or annular "corn-plasters," with frequent change of shoes, will usually suffice, however, to remove all but the most obstinate. Bunions belong to the care of the surgeon; they should not be trifled with. Corns should be treated with great care under any circumstances, and should never be cut with a razor or sharp knife. Scarcely a year passes without an account, in the medical journals, of death by tetanus, or "lock-jaw," as the result of indiscreet corn cutting.

The hands.—The care of the hands demands some notice. During the summer the hands are usually supple, moist, and in good condition, and require little attention beyond cleanliness. In cold weather, however, the hands of most persons tend to dry, crack and chap, unless taken care of. To prevent this occurrence, cold water should alone be used in washing the hands, and soap, sparingly or not at all, unless when absolutely required. The hands should not be washed just before going out of doors. If this must be done, a small quantity of cosmoline should be rubbed into the skin to prevent the action of the cold air. Gloves should always be worn in cold weather, and preferably they should be made of skin, as kid, dog-skin, castor, buck-skin, etc. Silken or woollen gloves are more apt to give rise to chapping. When the hands for any reason have become chapped, they should be anointed, on retiring, with some emollient, as perfumed tallow, rose ointment, etc., and gloves worn over night. In the morning the hands should be *wiped* off—not washed.

The finger-nails should always be kept well trimmed and smooth, and the skin pushed back about their roots, to prevent the occurrence of annoying "hangnails." The length of the nails should be moderate, neither too long nor very short, and their edges should be smoothly rounded. Long nails are receptacles for all kinds of dirt, and cannot be kept properly cleaned: they are also liable to split. Very short nails fail to protect the ends of the fingers, which are apt to become mis-shaped and clubbed in time.

The mouth.—The care of the mouth involves something more than merely the due cleansing of the teeth. The mouth is too often made the receptacle of articles of the most varied kind, which had better be placed almost anywhere else. The tongue, too, is abused in the same way, in being made to perform functions for which it was never intended, and is consequently exposed to numerous unnecessary dangers and injuries. The delicacy and thinness of the integument lining the lips and mouth and covering the tongue permit the absorption of matters placed in contact with this membrane, which would not affect other and more exposed parts of the general surface. The danger from this source, especially in the matter of contagion from certain diseases, is not altogether imaginary. No one who has been carefully brought up, or who is not extremely careless in his personal habits, will place in the mouth coins or other current property which passes from hand to hand among all kinds of people. When one has just seen a sheet of postage-stamps shoved across a dirty counter, on which all kinds of paper and metal coin, and many dirty hands, have been laid, one is loth to apply the delicate tip of the tongue to moisten it. But there are other points of contact, to some of which allusion need merely be made, in which proper care of the person would suggest caution. The handles of street-cars, books in public libraries, etc., are touched by every one, high and low, cleanly and dirty. If, therefore, one touches anything of the kind without gloves, one should be very careful not to put the fingers near the mouth without washing. The only safe rule, in fact, is to be as careful of the hands as if one were a dentist; never to put them near the mouth without having just washed them. This precaution may seem an unnecessary requirement; but, although the danger is small, yet the consequences of possible contagion are so terrible, that it may well be judged advisable to take every precaution in the manifold contacts of our daily life.

Attention has recently been called to the dangers lurking in a very unsuspected place, namely, the covers of children's books. These sometimes derive their brilliant coloring from poisonous dyes, which are, to a certain degree, soluble, especially in the fluids of the mouth, and may easily be absorbed by children in handling, and perhaps sucking, the covers.

The care of the teeth should begin at an early age; and parents should carefully instil good habits in this respect into their children. The period of shedding of the temporary teeth, and their replacement by the permanent set, lasts usually from about the seventh to about the thirteenth year. It is a critical epoch for the teeth; and not only should the most scrupulous attention to cleanliness on the child's part be exacted by the parent, but the aid of a competent dentist should be secured, under whose supervision the child should be placed, and to whom regular visits should be made for inspection. I think there is no doubt that many cases of decayed and deformed teeth, even among intelligent people, occur simply from early neglect. The temporary teeth must be removed in due time, the permanent ones trained to fill their proper places, and contact, with the certain resultant decay, prevented. The severe suffering which children often undergo with their decaying teeth is largely unnecessary, and can generally be prevented by due care and attention on the part of the parents.

Properly, the teeth should be cleaned on rising, on retiring, and after each meal. It is in fact more important to cleanse them after eating and before retiring than in the morning, since particles of food are sure to remain between the teeth after a meal; and whatever may happen to be between the teeth on retiring, rests there all night. A soft brush should be employed, since a stiff one wounds the gums, and causes them to retract, and it should be used either with water alone, or else first dipped in a little precipitated chalk, with which orris-root may be mixed to give an agreeable perfume. White castile soap may also be used to advantage at times. No further dentifrice is required; and such as contain cuttle-fish bone, charcoal, or pumice are injurious to a high degree to the enamel of the teeth. As a mouth-wash, a little tincture of myrrh dropped into a glass of water is aromatic and astringent, and is beneficial when the gums are spongy and tend to bleed. All further additions to the toilet of the teeth are purely cosmetic in character, and do not come under consideration here.

The hair.—The management of the hair in health is a simple matter. The first requisite is cleanliness. The epidermis of the scalp, like that of the body, is constantly being thrown off, and must be removed, while the glands of the scalp, particularly the oil glands, are very active, constantly pouring out their secretion, which spreads along the hairs by capillary attraction, serving to lubricate them and keep them in a glossy condition, but at the same time rendering them particularly liable to catch dust and floating particles. The best method of keeping the scalp and hair clean and in good condition is to brush them frequently and thoroughly with a soft brush. The scalp should be brushed—not merely the hair. A barber of experience said, "One cannot brush the hair too little or the scalp too much." Brushing stimulates the growth of the hair, and, where this is dry, tends to induce proper action of the oil-glands. It is much better for this purpose than the use of pomades, which should only be employed in case of such persistent dryness of the hair as prevents its being properly dressed. Persons whose hair is short, as children and men, derive advantage from plunging the head in a basin of cold water morning and evening, and then rubbing the scalp briskly with a coarse towel.

Under ordinary circumstances, frequent brushing is sufficient to keep the skin and the hair of the scalp clean and in good condition, and washing is only occasionally required. Travellers, however, and persons whose occupations expose them much to the influence of dust and dirt, as well as those whose scalps are by nature excessively oily, find it necessary to cleanse the scalp and hair more frequently. In such cases, plain Castile soap and water, or, where there is a tendency to the collection of scales ("dandruff"), a solution of borax in water may be employed to advantage. In individuals with long, thick hair, delay and annoyance is sometimes experienced in getting this properly dried. Occasionally women suffer from frightful attacks of neuralgia of the scalp, as the result of exposure to cold with the hair not perfectly dry. No one should venture out of doors in cold weather while the hair remains at all moist. Even when the individual remains in the house, the scalp should be thoroughly dried after washing. Water, if allowed to dry in the hair, promotes decomposition and rancidity of the natural oil, giving rise to a peculiar and disagreeable odor. To assist in drying long hair after washing, a brush may be dipped into a little finely powdered starch, which is brushed thoroughly into and through the hair, and is then brushed out again. Some pomatum may afterward be employed, or, better, some perfumed cosmoline, which, by the way, makes the best dressing for the hair, since, when of good quality, it is not liable to become rancid on keeping. In dressing the hair, the true use of the comb should be remembered, which is to separate the individual hairs from each other, to prevent matting, and to make the "part." The comb should never be used for the purpose of scraping the scalp to relieve itching sensations. The fine-toothed comb should be used sparingly in any case. When scales collect in the scalp to an extent which brushing will not remove, they should be washed out, and if washing, frequently repeated, does not suffice, medical advice should be taken. Troublesome and annoying disease of the skin is occasionally excited by the injudicious use of the comb.

The hair in children, and especially in boys, should be kept closely trimmed, not only for the sake of comfort and convenience, but also for that of cleanliness. In girls, after the hair has once been allowed to grow long, it is better not to cut it, as it is stated on good authority that the hair never afterward grows to the length which it would otherwise have attained. The hair, especially when thick and long, should in sickness be cut only with great caution, and under the direction of a physician. Occasionally, unfortunate results are reported from the sudden removal of the natural covering of the head under such circumstances.

"Crimping" the hair over hot irons or pencils sooner or later causes it to crack and break. This is not a matter of so great importance in young girls when the hair will grow again, but in the case of older women in whom the hair is beginning to thin out, it is apt to hasten the fall of what remains and to cause partial baldness over the forehead and temples. The use of soap in dressing the hair over the forehead, as is at present customary, where bandoline does not prove sufficient to preserve the desired shape, is sometimes injurious. In one case coming under my notice the hair, which had been a fine, dark shade of chestnut, was turned gradually to a rusty red by the continued use of "elder-flower" soap. In this instance white castile soap had been used with impunity, and, if soap must be used, this variety is likely to be least injurious, as containing less free alkali than others.

The hair usually begins to turn gray first on the head, the temples showing the earliest change. At the beginning white hairs are few, but their number soon increases. When they fall out they are frequently not reproduced, and, consequently, thinning usually goes hand-in-hand with graying. Women ordinarily preserve the color of the hair longest. Fair hair, while it is more persistent in color than dark, falls out earlier. Premature grayness of the hair is not unfrequently brought about by debility, anxiety, or severe illness. Grayness in tufts is ordinarily due to some local condition, either neuralgia or some unknown cause. The sudden blanching of the hair from fright, grief, or anxiety, which is now a well-authenticated fact, is of very rare occurrence.

Dyeing the hair, whatever may be the inducements for such a step, is, and must be, a most unsatisfactory procedure. If it is done to conceal the ravages of age, these cannot so easily be hidden, and no one is in reality deceived. But it is certainly a loss of dignity, and there is no question that a person who dyes the hair to look younger must lose, to a certain extent by this weakness, the good opinion of those whose regard is most to be desired. Every one smiles at the thought of the would-be youthful people whom one sees, with the complexion of a peach, melting into "crows' feet" at the corners of the eyes, and through whose raven locks can easily be seen a play of iridescent color like that of the "sulphurescent" glass lately in vogue. Notwithstanding the marvellous stories one sometimes hears of the pernicious effects of hair-dyes upon the system, I am inclined to believe that none of those in common use are injurious. No authentic case of general poisoning from the use of arsenic, nitrate of silver, or sugar of lead as a hair-dye, has, to my knowledge, been recorded; and these are the substances usually employed.

Each hair grows from its "papilla" within the skin, lives its life (from two to four years in healthy persons), and then dies and drops out, to be succeeded by another; as certain "annual" plants grow year after year from the same bulbous root and die down again. If from any cause the hair papilla becomes diseased or debilitated, it either ceases to produce the hair, or each successive hair becomes shorter, finer, and more brief in its life until, finally, atrophy of the hair follicles occurs and the hair is dead. Under ordinary circumstances the hair of the head begins to thin out between the ages of thirty and forty, and this thinning proceeds slowly but steadily during the rest of the individual's life. But a number of causes combine to induce a premature fall of the hair in many persons, and among these may be mentioned certain diseases of the skin, particularly that known among physicians as seborrhœa, or, commonly, as "dandruff." When in a young person an excessive degree of scaliness is observed in the scalp, measures should be taken to cure this condition; otherwise, before long, the hair will in all probability begin to fall. When this latter stage is once established, it is usually too late to do much good; the falling of the hair continues, and sooner or later, particularly in families where there is a hereditary tendency to baldness, more or less complete loss of hair over the forehead and crown of the head ensues. It is true that gradual progressive baldness is sometimes observed without any disturbance of the general system and without the occurrence of "dandruff." On the other hand, "dandruff" of the scalp is now and then observed in persons whose hair is uncommonly thick and strong. This latter circumstance is very unusual, and has given rise to the erroneous notion that "dandruff" in the scalp is a sign of peculiar vigor of the hair.

Other causes of premature baldness are: the occurrence of certain diseases of the scalp other than "dandruff," and certain debilitated conditions of the system occurring alone or following severe fevers, etc. Usually the baldness occurring in connection with skin diseases of the scalp is only temporary; the bulbs not being destroyed, the hair is again reproduced so soon as the skin disease is cured. The same may be said of the baldness or thinning of the hair following fevers. When these occur in young persons, the hair frequently recovers after a time its strength and thickness, but in older persons it rarely returns to its former condition. Thinning of hair in states of chronic debility is usually irremediable unless the whole condition is permanently improved, and not then if the individual is no longer young.

The remedies employed for the relief of baldness are all stimulants intended to increase the circulation of blood in the skin about the roots of the hair. When the falling of the hair has been caused by some fever or other illness, such "invigorators" are of use, and where it is connected with general debility of the system these may also be employed to advantage in connection with proper medical treatment. When, however, the hair in young persons begins to fall out, either with or without the concurrent appearance of "dandruff," the best medical advice is required to prevent, if possible, the inevitable baldness which will sooner or later ensue. Where there is a hereditary tendency to baldness it is frequently the case that no treatment avails.

Abnormal growth of hair most frequently occurs in females upon the upper lip or chin. This is sometimes excessive, as in the case of the bearded women occasionally exhibited publicly. Women who possess this unfortunate peculiarity are not necessarily in any way deficient in the best characteristics of the sex. By the kindness of my friend, Professor Duhring, I had an opportunity, a year or two ago, of examining a young married woman who displayed a large, full, and very handsome coal-black beard and moustache. This person was of a delicate figure, with a soft voice and pleasing manner, and a degree of refinement unusual among persons of her station.

Frequently more or less considerable patches of hair are found in other and abnormal parts of the face and body, and cases are recorded of "hairy" men and women in whom a greater or less proportion of the whole surface has been covered with hair.

None of the means formerly used to remove superfluous hair have proved effectual. Extraction only stimulates its more rapid growth, and depilatory powders, besides being caustic and consequently often injurious to the skin, only destroy the outer end of the hair, leaving the root intact. Recently, however, more effectual methods have come into use, and are known to physicians, whereby this unsightly deformity can be remedied.

Of the various diseases of the hair, splitting, knotting, etc., this is not the place to speak, although a few words may be said about the care of the hair in general sickness. This resolves itself, practically, into cleanliness. The hair should never be cut in sickness, excepting by the physician's express order. In the case of women I think it should in no case be cut. Constant brushing and examination of the scalp should be practised in severe illness, and the hair should not be permitted to become matted, as even in the cleanest persons we find it harboring vermin occasionally, coming from no one knows where. Even where these occur, the hair need not be cut; if appropriate remedies are used, the scalp can be completely cleansed without this sacrifice.

EDITOR'S NOTE.—For various reasons it has been thought best to make no allusion in the present chapter to the hygiene of the eye and ear. The former subject is discussed in the chapter on School Hygiene (Vol. II., p. 605), and the chief precautions which it is needful to take in order to preserve the hearing are briefly given below.

All attempts to clean the deeper portions of the outer passage of the ear by means of ear-spoons and other contrivances are unnecessary, and sometimes give rise to inflammation. In health—and it is only with a healthy state of the body that we are here concerned—the deeper parts of the ear can be left to take care of themselves. The orifice of the canal is to be cleaned in precisely the same manner as any other depressed portion of the surface of the body—that is, with a wet cloth or sponge.

Bathing in salt water may injure the ears in two different ways. The water may gain an entrance into the external canal, and by its irritating properties set up inflammation. This is generally supposed to be the way in which bathing in salt water gives rise to inflammation of the ear. From personal observation, however, I am disposed to believe that in the great majority of cases the disease is caused in another way. In the manœuvres incident to diving, swimming under water, floating on the back, etc., the nasal passages become filled with salt water. The bather then yields to an almost irresistible desire to "blow his nose," in order to get rid of the irritating fluid. The blowing is generally of a vigorous character, and often forces some of the salty fluid up through the narrow passage (Eustachian tube) which leads from the back part of the nose to the drum cavity, where its presence may give rise to even very severe inflammation. If the bather is careless, or not familiar with the surf, his ears may receive injury from the mere impact of the waves. Sand may also enter the outer passage with the water, and aid in setting up inflammation. In answer to the question: What can be done to avoid these injurious effects of bathing? I would simply say: After the bath abstain from blowing the nose in any but the gentlest manner until after all the active secretion of mucus has ceased. By that time the salt water will have been got rid of, and "blowing the nose" may be indulged in again with wonted vigor. Shall cotton be worn in the ears? Yes, if the bather has reason to believe that he possesses an irritable skin, if he has previously had some affection of the external auditory canal, or if he knows that his drum-head is perforated. Otherwise, the protection afforded by the cotton is too slight to compensate for the annoyance which it causes.

The question of contracting deafness from habitual exposure to noises of a certain character is referred to in the chapter on Hygiene of Occupation (Vol. II., p. 70).

PART II.

HABITATIONS.

SOIL AND WATER.

BY

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SOIL AND WATER.

Conditions of the Soil affecting Health.

THE term soil is here used in its broad sense, as comprehending so much of the crust of the earth, of whatsoever composition and arrangement, as may, in any manner, give rise to conditions affecting health. These conditions may be due solely to the operations of nature, unmodified and uninfluenced by human agency, or they may be the direct or indirect result of the interference of man. Under the former class we may cite, as examples, dampness of the soil (which is a prime factor in the causation of many diseases), and those peculiar conditions of the natural soil originating the morbific exhalations described by the term *malaria;* and under the latter those conditions of the soil resulting from its pollution, and giving rise to diseases pointedly and significantly designated by Mr. Simon as "filth-diseases."

For convenience of description, an arbitrary division of the soil into surface-soil and subsoil has been made, the latter being designated as the stratum of the earth which lies immediately beneath the surface-soil.

The general subject of soil and water may be conveniently studied under the three divisions of *constituents of the soil, pollution of the soil,* and *diseases produced by conditions of the soil.*

The constituents of the soil form the groundwork of the theme, and must be carefully studied, sufficiently in detail, to determine their agency in the production of disease, with a view to point out the best means of modifying, counteracting, or preventing all such influences derived therefrom as may be antagonistic to health. The second branch of the subject treats of the pollution of the soil, its causes and means of prevention. It involves a study of the methods of disposal of excreta and of refuse matters from habitations and various trades, of the construction of street pavements, the conservancy of surface area, the disposal of the dead, and all means of preserving the purity of the soil and ground-water; and, finally, we shall endeavor to trace the influence of certain conditions of the soil in the causation of disease, as derived from excess of water in the soil—"the ground-water theory"—from emanations from the natural soil, from pollution of the soil, and from pollution of drinking-water.

SECTION I.

CONSTITUENTS OF THE SOIL.

The soil consists of distinct mineral masses variously arranged, and considered by geologists under the term *rock*, which is meant to apply to all these "substances, whether they be soft or stony, for clay and sand are included in the term, and some have even brought peat under this denomination." Organic matter, both animal and vegetable, is also associated with these substances in variable quantities and conditions. Air and water form other and important ingredients of the soil. From a sanitary standpoint these latter elements furnish an exceedingly important topic for consideration, since it is almost exclusively through their agency that whatever is hurtful in the soil is brought in contact with the human body.

1. *Air in the Soil.*

The atmosphere penetrates the earth and circulates beneath its surface to an indefinite depth. This fact, in its relation to the superficial soil, is practically recognized by the scientific agriculturist, but it has a different and not less important significance to the sanitary scientist, and should be a well recognized popular truth. All rocks are more or less porous, that is, endowed with the capacity for holding air as well as water; and most uncrystallized sedimentary ones possess this character in a very considerable degree. From actual experiment (Hunt),[1] the volume of water (air) enclosed in 100 volumes of various rocks having been determined, it was found for three specimens of Potsdam sandstone to equal 6.94–9.35; for specimens of crystalline dolomite, 5.90–7.22; for three specimens of fine gray Devonian sandstone from Ohio, much used for building, 20.24–20.62–21.27; for specimens of dolomite, Guelph, 10.60; of dolomite, Chazy, argillaceous, 13.55; and for three specimens of soft limestone of Caen, France, so much employed in that country for architectural purposes, 29.49–29.54–29.93. Some kinds of very porous sandstone contain air to even one-third of their bulk. Sand, gravel, and soils contain air in very large proportions—loose sand, in extreme cases, to the amount of fifty per cent. The air of moderately well pulverized soil may amount to no less than one-fourth of the whole bulk, and loose soils turned up for agricultural purposes may contain as much as from two to ten times its volume of air (Parkes).

A familiar illustration of the capacity of the soil for air is afforded by the well-known fact that when soil is disturbed it fills a greater space than it occupied before. The same fact is demonstrated by filling a vessel

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[1] Chemical and Geological Essays, 1875.

with earth and adding water to saturation. The amount of water absorbed represents the amount of air displaced, and this method may be employed for making a rough estimate of the relative porosity of different soils.

The following experiment, devised by Pettenkofer, demonstrates the facility with which air passes through compact soils, and even apparently solid substances.

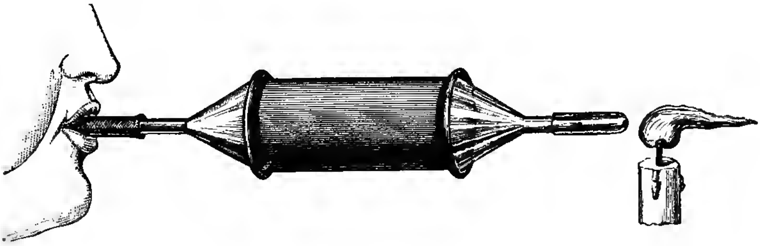

FIG. 1.

Fig. 1 represents a cylinder of solid, dry mortar, half lime, half sand, 5 inches by $1\frac{2}{3}$ inches. With the exception of the two ends, it is covered all over with melted wax, which is impervious to air. To each end of the cylinder is attached, by means of wax, a glass funnel which terminates in a tube. By blowing through one of these tubes it will be found that the air will pass through the solid mortar and cause the flame of a candle held near the end of the opposite tube to sensibly deviate. By an effort it may be extinguished altogether. The porosity of soils is also well illustrated by an experiment represented at Fig. 2.

As in the atmosphere, so in the ground-air; oxygen, nitrogen, and carbonic acid form the main constituents, though the proportions of these elements are subject to constant and marked variation. Moisture is also present, and, in addition, are found traces of ammonia, and, occasionally, carburetted and sulphuretted hydrogen. With reference to the effluvia and finely suspended particles of organic matter derived from animal and vegetable substances existing in the soil, little can be said, for as yet our knowledge upon this point is very imperfect.

The recorded observations of Pettenkofer, Fodor, Fleck, Lewis and Cunningham, and Nichols, made within recent years, have given considerable prominence to carbonic acid as one of the constituents of the ground-air. It has been found to exist in remarkable excess of the amount contained in atmospheric air, and is exceedingly variable in quantity. Being derived from organic processes of oxidation occurring in the soil, it is in amount inversely as the oxygen.

Boussingault's investigations[1] were made in the interests of agriculture and were conducted in soils to the depth of about fifteen inches. The quantity of carbonic acid determined by him varied from 2.4 to 9.74 per 1,000 volumes of air, the air for the latter experiment being taken

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[1] Zeitschrift für Biologie, VII., p. 395.

from a recently manured soil. The examinations of the air of the alluvial soil in the neighborhood of Munich, made by Pettenkofer[1] in 1870–1871, revealed the fact that the amount of carbonic acid increased with the depth, and varied according to season, its minimum being reached in winter and its maximum in summer. The amount per 1,000 volumes of air varied from 1.58 at a depth of 5 feet, to 18.38 at a depth of 13 feet. Subsequent determinations made by Pettenkofer in the neighborhood of Munich, and by Fleck in the vicinity of Dresden, showed the proportion to be frequently even greater than the maximum just mentioned, and on one occasion it was as high as 80 per 1,000.[2]

Fodor,[3] of Buda-Pesth, experimented on air in different localities at the depth of 3¼, 6½, and 13 feet, and likewise found the greatest amount of carbonic acid at the lowest depth, it being in the enormous proportion of 107.5 per 1,000; at a depth of 3¼ feet, in one case, it was only 3.7 per 1,000. The test also revealed the presence of ammonia, but no sulphuretted hydrogen. The observations of Lewis and Cunningham,[4] made at Calcutta, were somewhat similar in their results, the deepest-lying strata furnishing the largest amount of carbonic acid.

Nichols[5] has made an examination of the "Back-Bay lands" in Boston, which consist of mud covered over mainly with gravel. The air was taken 3½ feet below the surface, at different times and at different levels of the ground-water. The amount of carbonic acid determined varied from 1.49 when the water-level stood at 3 feet 10½ inches from the surface of the ground, to 2.26 per 1,000 when the surface of the ground-water was at a depth of 4 feet 2 inches. No sulphuretted hydrogen was detected, but slight traces of ammonia were found. In another locality, where the sand was 10 feet in thickness, the results were quite similar, except that a larger proportion of carbonic acid was present. A more extended series of experiments was made at still another locality in the "Back-Bay lands," at a depth of from 6 to 10 feet. They were commenced in May and continued until the close of the year 1874. As in the other examinations, traces of ammonia were found, but no sulphuretted hydrogen. The difference in the amount of carbonic acid found at different depths was not always very noticeable, though many of the observations showed a greater amount at 10 feet from the surface than at a depth of 6 feet. The amount of carbonic acid varied from 3.23 per 1,000 at a depth of 6 feet—observed in December—the water-level being 11 feet 11 inches below the surface, to 21.21 at a depth of 10 feet—observed in August—the water-level being 10 feet 8½ inches.

The amount of carbonic acid in the ground-air has been proposed by Pettenkofer as a measure of impurity, but he admits the possibility of a better index of impurity being found when investigations shall have been

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[1] Annales de chimie et de physique (3), XXXVII., pp. 5–50.

[2] Sixth Report of Board of Health of Massachusetts, 1875, p. 209.

[3] Deutsche Vierteljahrschrift für öffeutliche Gesundheitspflege, VII., p. 205.

[4] The Soil in its Relation to Disease, Calcutta, 1875.

[5] Sixth Report of Board of Health of Massachusetts, 1875, p. 213.

more accurately and extensively made. Fodor dissents from this opinion, and cites as his reason the conclusion arrived at from repeated examinations of the ground-atmosphere, namely, that the carbonic acid is not produced by oxidation on the spot, and therefore cannot be taken as a test of impurity of the air of any given soil.

Nichols[1] seems to hold substantially the same view of the subject, for he says: "It is to borne in mind that the amount of carbonic acid found at any time is the difference between the amount actually produced and the amount carried off by diffusion and by the ground-water. The amount, then, that is found in different soils and under differing conditions, cannot be taken as a measure of the intensity of the processes concerned in its production, for very much depends on the character of the soil, especially in the matter of porosity. At present it does not seem to be possible to draw much useful information from the determination of the carbonic acid in the ground-air. As the numbers of the determinations increase, and the laws of the variation are better understood, it is possible, that, like the height of the ground-water, it may be found to connect itself with causes and effects of sanitary importance." This point seems to be as yet undecided; nevertheless, the suggestion of Pettenkofer should not be discarded until proved of no value by the results of more extended researches.

The porosity of soils, or, in other words, the measure of capacity for air, is estimated in different ways. A rough estimate may be obtained "in the case of rather loose rocks, by seeing how much water a given bulk will absorb, which can be done by measuring the water, before and after the weighed or unmeasured rock is inserted in it, or by weighing the rock after immersion."[2] A more accurate plan is that adopted by Hunt.[3] Small broken fragments of rock are carefully dried at about 200° F., till they cease to lose weight. The weight having been determined, they are then placed with their lower portions in water, and allowed to remain for some hours, after which they are covered with water and placed under the exhausted receiver of an air-pump, by which process a large portion of the air is removed. The exhaustion of the receiver is several times repeated, at intervals, until the portions of the rock are as nearly as possible saturated, and bubbles cease to escape on further exhaustion. They are then removed, carefully wiped with blotting-paper, and again weighed—first in air, and then in water.

"The loss in weight of the saturated rock when weighed in water being equal to that of the volume of water displaced by the mass, enables us to determine the specific gravity of the latter; while this loss in weight, less the weight of the water absorbed by the mass, gives the true volume of water displaced by its particles, and hence the means of determining their specific gravity. The division, by the volume of water

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[1] Sixth Report of Board of Health of Massachusetts, p. 220.

[2] Parkes: Practical Hygiene, 5th edition, p. 328.

[3] Chemical and Geological Essays, 1875, p. 164–166.

displaced, of the amount of water absorbed, gives the absorption by volume; and the division of the weight of the water absorbed by that of the dry mass, the absorption by weight."

The following formulæ, furnished by Hunt, are of value in estimating the relative amount of air, as well as the relative amount of water, absorbed by the different rocks:

$a =$ the weight of the dry rock.
$b =$ the weight of water which the rock can absorb.
$c =$ the loss of weight, in water, of the saturated rock.

We have then the following equations:

1. $c : a :: 1{,}000 : x =$ specific gravity of the mass, or apparent specific gravity, water being 1,000.
2. $c - b : a :: 1{,}000 : x =$ specific gravity of the particles, or real specific gravity, water being 1,000.
3. $c : b :: 100 : x =$ volume of water absorbed by 100 volumes of the rock.
4. $a : b :: 100 : x =$ weight of water absorbed by 100 parts, by weight, of the rock.

Parkes furnishes the following convenient formula:[1]

$$\frac{\text{Weight of water taken up} \times 100}{\text{Weight of dry rock} \div \text{specific gravity}} = \text{percentage of air.}$$

The same author gives the following plan adopted by Pettenkofer when the soil is loose: Dry the loose soil at 212° F. and powder it, but without crushing it very much; put it into a burette, and tap it so as to expel the air from the interstices as far as possible; connect another burette by means of an elastic tube with the bottom of the first burette, and clamp it on; pour water into No. 2 burette, and then, by pressing the clamp, allow the water to rise through the soil until a thin layer of water is seen above it; then read off the amount of water thus gone out of the second burette. The calulation is:

$$\frac{\text{Amount of water used} \times 100}{\text{Cubic centimetres of dry soil}} = \text{percentage of air.}$$

Except, perhaps, in the more dense rocks and compact clays, the air beneath the surface of the soil circulates more or less freely, according to a combination of external influences, aided by the condition of porosity of the soil. The facility with which water permeates the soil is a matter of common observation; air being so much lighter (770 times lighter than water), it can be readily seen why it should have still greater power of diffusion, and be even more movable than water. The causes to which

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[1] Practical Hygiene, p. 328.

the movement of the ground-air is attributable are—the difference of temperature between the surface and the deeper strata, the force of the wind, barometric pressure, displacement by rain-fall and movement of ground-water, and the inherent power of diffusion which gaseous bodies possess. The force exerted by the wind is apt to be underestimated. The pressure exerted upon a square foot of surface varies from 1.107 pounds during a "brisk wind" blowing at the rate of fifteen miles per hour, to 50 pounds during a "hurricane" with a velocity of 100 miles an hour.[1] The effect of the unequal pressure of the atmosphere upon the ground-air is well illustrated by Fig. 2.

The following experiment, devised by Prof. Pettenkofer, illustrates in a striking manner the motion of the air through the ground.

In Fig. 2, *A* represents a tall glass tube filled with gravel, *E*, in the axis of which stands a smaller glass tube, *B*, one open end of it reaching to the bottom. The other open end of the small glass tube is attached by means of a piece of india-rubber tubing, *C*, to a U-shaped tube, *D*, containing water. "If a person blow, as represented in the figure, on the surface of the gravel, the liquid in the U-shaped tube will be seen to alter its position, the level of the side next the person who is blowing becoming lowered, and the other proportionally elevated. The depression of the fluid is caused by the force of the air blown through the gravel, because it ascends from the bottom of the gravel through the small glass tube, passes through the india-rubber tube, and thus reaches the water." If the water in the curved tube, *D*, be removed, by blowing in the same manner upon the surface of the gravel, the air passing through the gravel and through the tubes will escape at the outlet beyond *D*, with sufficient force to blow aside the flame of a candle. In the light of this experiment, it is not difficult to see how the air in the ground can be set in motion by the pressure of air or wind against its surface.

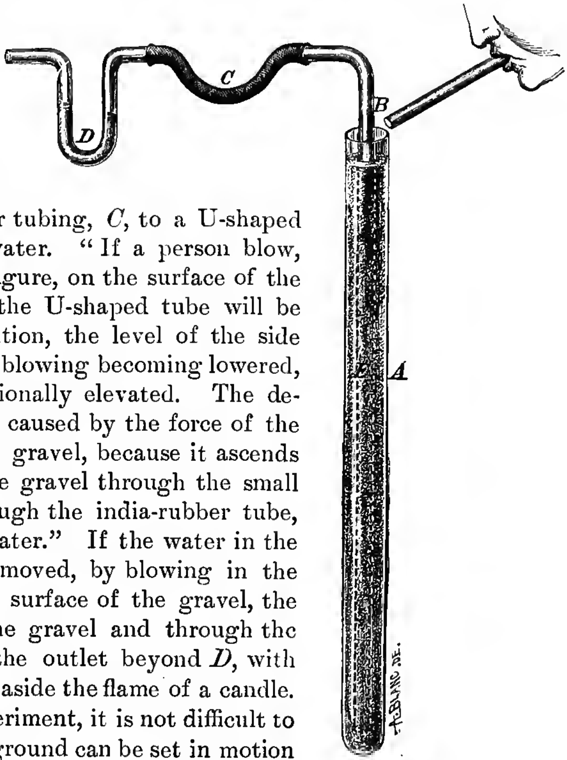

FIG. 2.

The fact of the continual movement of the ground-atmosphere has an important bearing upon some causes of disease, especially those associated with impurities of the air of our houses derived from the subsoil. It indicates an inquiry upon a subject which has hitherto received but limited attention, and suggests the importance of the investigation of influences

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[1] The American Cyclopædia, Vol. XVI., Article—Wind.

hidden from sight, yet potent in undermining health, if not directly causative of disease. The cellars of houses, as usually constructed, form no barrier to the escape of air from the subsoil. When artificially heated, the force of suction is added to the other forces at work in causing an upward current of air. In this way air may be drawn from a great depth, as well as from a distance laterally, and will convey with it impurities (it may be disease-germs) derived from the various sources of contamination so frequently present about and under our habitations. In this manner, coal-gas, effluvia from privy-wells and cesspools, sewer-gas from defective drain-pipes and imperfectly constructed sewers, and the exhalations from a filth-sodden soil, which too frequently forms the foundation and local surroundings of dwelling-houses, pollute and poison the atmosphere we breathe.

To prevent the pollution of the ground-air, is of primary importance. This may be accomplished by removing the sources of contamination, and by facilitating the natural processes of purification and relieving the over-taxed powers of the soil by drainage and aëration. Then, in the second place, protective measures may be resorted to for additional security. As has been shown, it is impossible to prevent the circulation of ground-air, but, by suitable devices, it may be diverted into other and less hurtful channels, and its pernicious influence reduced to a minimum. This can be accomplished by laying the basement-floors of the entire dwelling, as well as the foundation-walls, on a bed of concrete, as shown in Fig. 3, A, and by using damp courses, B, made of impervious materials, such as cement and slate, or asphalt, or vitrified stoneware tiles, between the layers of stone in the walls just above the ground-level. By these means both the dampness and air of the underlying soil will be prevented from entering the building. A layer of good asphalt, C, placed over the concreted basement floors will make an excellent finish, and will more completely secure the object desired. An additional protection will be secured by having a dry area between the surrounding ground and the external walls, as represented in Fig. 3. The area should be well drained and ventilated. When the subsoil is very impure, as is often the case when the site

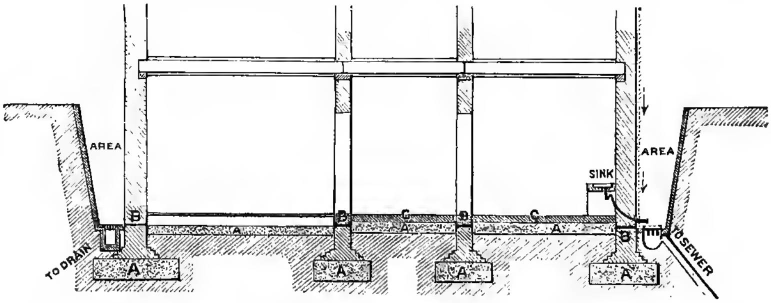

Fig. 3.—Basement Floor. Arrangements to exclude ground-air and dampness. A, concrete bed; B, damp-proof course; C, asphalt floor.

selected is upon "made-ground," a good layer of charcoal may be interposed with advantage, as suggested by Rawlinson. It may even be advisable, in some cases, to raise the house above the ground-surface, that a free ventilation may be secured between the lower floors and the ground. In many of the summer resorts along the coast, this practice has become a sanitary necessity, on account of the peculiar formation of the soil.

The paving of towns undoubtedly lessens the ascent of effluvia and diminishes the chances of soil-pollution from surface-impurities, but by impeding the upward circulation of the confined air, it may tend to increase the liability of the house-air to defilement by diverting the ground-air, frequently charged with coal-gas and sewer-gas, toward the least resisting and unprotected channels of exit offered by carelessly constructed cellar floors. Cases are on record which seem to prove the correctness of the statement. The means of protection above suggested will guard against this casual source of danger.

A suggestion has been made[1] with the twofold object of preventing the ingress of ground-air into our dwellings and of affording a means of ventilation of the soil. It is to have a ventilating chamber constructed under the entire surface of the cellar floor, separated from the basement by an intervening pavement of some impervious material, such as asphalt. This chamber is to be one foot in depth, and connected with a chimney-flue, so as to carry off the ground-air which rises into it in autumn, winter, and spring. During the summer, when the ground-air beneath the house sinks, a current of fresh air passes downward and rises to the heated surface outside the house.

Provision should be made for facilitating the ventilation of the soil in cities where the surface is covered by pavements, which more or less impede the free passage of air. The free admission of the atmospheric air into the ground is beneficial by diluting the ground-air, and by preventing its stagnation, and by promoting the oxidation of organic matters. This may be secured, to a great extent, by reserving numerous places for public squares, and spaces adjoining houses for garden plots, which should be covered with vegetation. Care should be taken that these places are not suffered to become polluted by surface-defilement, in which case the last evil would be worse than the first.

Porous soils being, as a rule, considered healthy, on this account the precaution to intercept and cut off, by suitable means, the ascent of ground-air into houses should not be omitted, since such soils are sometimes malarious, and they may, on account of their porosity and the suction power of the heated air of houses, allow impurities to be conducted from a long distance.

The nature of the impurities of the air derived from the soil under various conditions has been fully discussed elsewhere. We shall, therefore, in this place, simply allude to some of the more prominent sources

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[1] Staebe and Niemeyer: Boden-Ventilation, als Schutzmittel wider Cholera und Typhus, 1873.

of pollution of the ground-air, and, through this channel, of the atmosphere we breathe. The mephitic gases from cesspools and privy-wells, and even the fluid contents, may pass into the surrounding soil, and charge the ground-air with morbific elements. Sewage emanations, and likewise the sewage itself, escape into the ground, saturate it with impurities, and supply the more important conditions favorable to the further contamination of the ground-air. The omission to remove solid and liquid offensive matters from inhabited places is another and very common cause of "ground-air" pollution. These matters, by soakage, fill up the interstices of the soil, and, under favorable conditions of heat and moisture, usually present, undergo changes that give rise to the development of noxious effluvia, which are important factors in the causation of disease. From all these sources may be produced not only gaseous products of organic decomposition, which are dangerous to health in proportion to the degree of concentration, but other and more important agents in the production of disease, those morbific ferments, or "septic ferments," as they have been called, which seem to be inseparably connected with certain palpable elements or organisms, of microscopic minuteness, and which find favorable conditions for development in soils loaded with oozings from sewers and cesspools, and from refuse heaps and middens.

The emanations from the soil of graveyards and cemeteries generally contain putrid organic matters, an excess of carbonic acid, and the low forms of cell-life. Independent of human agency, there are emanations that take place from the soil, particularly of low, marshy lands, which give rise to certain forms of fever, to which the term *malaria* has been commonly applied. "It has been frequently affirmed as a general truth that the great difference of one country from another, in point of salubrity, consists in the greater or less proportion of soil which produces noxious effluvia." The nature of malaria has been a subject of the widest speculation. Of the numerous hypotheses promulgated from time to time, not one has been accepted as explaining fully what the poison is, and the true and essential causes concerned in its production. Certain conditions of the soil and states of the atmosphere have been described as being generally associated in regions where malaria prevails; but instances occur in which, with all the conditions present that appear to be favorable for the development of the poison, there is complete immunity from the diseases it is said to produce; while, on the other hand, well authenticated examples are not lacking of regions notoriously malarious, where the conditions (mainly of the soil) which appear to be most essential for the development of the malaria are entirely absent. The instances of malaria in elevated regions, where the soil is dry and is clothed with scanty vegetation—as, for example, in the Tuscan Apennines, on the Pyrenees, and on the lofty mountains of Peru, at an elevation of 10,000 feet—are cases in point. These apparent contradictions only go to show how imperfect is our knowledge of the nature and causes of malaria. The theory that malarial fevers are caused by exhalations from the soil charged with the products of decomposition of vegetable organisms, by virtue of some subtle poison they contain, or by a combination of several factors, is a very common one. Some observers maintain that the poison is elaborated in the soil, and is communicated by the agency of drinking-water. Others attribute the poison to exhalations from living plants, and to subterraneous gases of volcanic origin. Heat, electricity, and chill have all been assigned as causes of malarial fevers. The theory that the active principle causing these diseases resides in the low forms of vegetable organisms, spores of algæ, has also been revived of late years. Sufficient is known of the conditions under which malarial fevers do occur, without determining the active principle of causation, to warrant the conclusion that the agent is associated with "some kind of decomposition or fermentation going on in the soil, especially when conditions come together of organic matter in the soil, of moisture, heat, and limited access of air." (Parkes.)

The diseases which have been attributed to emanations from the soil are (as stated by Dr. Parkes) paroxysmal fevers, enteric fever, yellow fever, bilious remittent fever, cholera, and dysentery.

This formidable array of maladies, all belonging to the class of preventable diseases, suggests a wide and fruitful field for accurate sanitary investigations.

2. *Water in the Soil.*

The water in the soil may be conveniently studied under the two divisions of *moisture* or dampness, and of *ground-water*. The term moisture is used to designate water in the pores of the soil in contact with air, the amount ever varying according to the nature of the soil, influences of heat, and conditions of supply, etc. Ground-water, a term derived from the German "Grundwasser," is the continuous stratum or body of water formed by filling to repletion all the pores and spaces in the soil to a certain level, found at different depths beneath the surface of the ground. The surface of this sheet of water is called the water-level, water-table, or line of saturation in the soil, and forms a distinct boundary between the underlying saturated soil and the ground above it which is merely moist, that is, contains water *and* air in variable quantities.

There is the greatest difference in soils with respect to their power to absorb and retain moisture; scarcely any are without it, and some possess the property to a very remarkable extent. Nor is this property confined to the disintegrated materials combined in the formation of soils; the rocks from which they originate, even those of the denser structure, are capable of taking up a certain amount of water. Ordinary uncrystalline sedimentary rocks, and even granite and trap-rock, absorb moisture. Some of these formations when taken from the quarries are more or less saturated with water. The more compact gravels contain pores or spaces to the extent of one-third of their bulk, which may be filled with water as well as air. This may be clearly demonstrated by filling a vessel with gravel and pressing it down so compactly that the bulk of the gravel can no longer be diminished, and then by noting the amount of water that can be poured into the vessel which was, apparently, entirely filled with gravel. The quantity of water taken up by the dry gravel will amount to about one-third of its volume. Such a soil as this constitutes the foundation of the city of Munich, which has been the subject of careful and noteworthy investigations at the hands of Pettenkofer.

A strong clay soil may retain 27 per cent. of water; a moderately heavy soil, 30 to 31 per cent.; a sandy loam, 33 to 36; and a black loam rich in *humus*, 41 per cent. (Wolff.) *Humus* is exceedingly tenacious of water, and, according to some experimenters, may contain as much as 60 per cent. of its volume. Dried quartz can take up a large per cent. of water, and even sands have the power to contain moisture to a considerable degree. A new well-made brick will hold as much as a half-pint of water. Chalk takes up from 13 to 17 per cent., some sandstones as much as 20 per cent., and granite from 0.4 to 4 per cent.

An examination made with reference to the choice of building-stone for the Houses of Parliament in 1839, developed some interesting facts pertinent to the present subject. Some of the results may be cited. It was found that the absorption of water for 100 volumes of rock was as follows:

For three silicious limestones, 5.3, 8.5, and 10.9; for four nearly pure limestones from oölite, 18.00, 20.6, 24.4, and 31.0; for four magnesian limestones, 18.2, 23.9, 24.9, 26.7; and for six sandstones, 10.7, 11.2, 14.3, 15.6, 17.4, and 22.1.

In all the experiments, the air was removed by placing the rock in water under the vacuum of the air-pump; the amount of water absorbed by simple immersion would, in all cases, be much less.

Rain is the principal source of moisture in the soil. The amount absorbed depends upon the nature, condition, and situation of the soil. The inclination of the ground, and the facility for superficial drainage; the previous state of the soil as to moisture; the character of the rainfall—which may be so rapid as to partially prevent absorption, much of the water passing off by the natural channels of drainage; agencies promoting evaporation, such as heat, wind, etc.—all influence the amount of rain passing into the ground.

Another source from which the soil derives moisture is through its power of attracting the vapors of water in the air. In rainless, tropical regions this property of the soil is of the greatest value. But a more important source, in the present connection, is presented by the ground-water itself. From the surface of this underground lake a constant distillation of water is taking place toward the surface of the ground. By capillary attraction a quantity of moisture from the deeper-lying, saturated strata is constantly being imparted to the superincumbent layers. The humidity of the soil is further dependent, and to a very considerable degree, upon the rise and fall of the ground-water.

The amount of moisture in a given soil may be determined roughly by drying a weighed quantity in a drying-chamber, and noting the loss of weight; then by heating it in a steam- or air-bath until it ceases to lose weight. The entire loss of weight will give approximately the amount of moisture contained in the soil. To determine the power of absorption in any soil, dry a sample of it by exposure to heat sufficient to drive off all the moisture; then weigh it, and expose in a shallow tray to the atmosphere, and note the increase of weight under different conditions of temperature and humidity of the atmosphere, at night as well as in daytime, to determine the amount of water it will condense from the air. The dried soil may also be exposed to the atmosphere saturated with moisture by placing it under a bell-jar in a shallow tray, together with a shallow vessel of water. The weight of the dried soil being known, any changes will be observed by weighing it, from time to time, during twenty-four or forty-eight hours. A more exact mode of determining the amount of water absorbed by soils and rocks has been presented on a previous page.

The subterranean water-bed is formed by the arrangement and structural character of the subjacent strata. The dip of the underlying impermeable strata, and their relative position to the surface of the ground, determine the depth of the soil-water. Its level, instead of being at or near the surface, as in a marsh, may be at a very great depth.

The ground-water is in continual movement, generally toward the sea or nearest watercourse. The movement is influenced by the amount of rain-fall, the resistance encountered at the outfall, and by the topographical relations and physical properties of the soil. The roots of trees are said to retard the flow of the ground-water.

The velocity of the flow is never great, it may be hardly perceptible. In Berlin, according to Virchow, the movement of the ground-water towards the Spree is very slight; in some places it is almost null; while in Munich, where extended observations have been made by Pettenkofer, the rate of movement toward the Isar is fifteen feet daily. The water-table is subject to constant changes; the variations and rapidity in its rise and fall differ very much in different places and at different seasons of the year. In some places there is but slight variation in the level of the soil-water, in other places the difference between the highest and lowest water-level in the year may be many feet. This is particularly the case in those regions where the rain-fall is confined to particular seasons of the year, and is excessive, as in certain parts of India, for example, where the difference between the maximum and minimum depression of the water-level has amounted to seventeen feet.[1]

As has been intimated, the variations in the water-level are caused by the amount of rain-fall and evaporation, changes in the character of the passages of escape, and the resistance of the water at the outlet. High tides and freshets may cause a very perceptible rise in the level of the soil-water. The amount of rain-fall cannot be taken as a reliable measure

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[1] The limits between the highest and lowest water-level in the year are 10 feet in Munich, nearly 17 feet at Saugor, India, and 13 feet at Jubbulpore. At Calcutta and Bombay the changes are also very marked.

of the state of the ground-water, since the effects of rain are frequently only appreciable after the lapse of considerable time, and are often more marked at a distance from the area of rain. The same amount of rain does not affect all soils alike, and the same soil in different years, with the same quantity of rain, shows a marked variation in the level of the ground-water. The height of the water-level may be easily determined by taking the measurement of the surface of the water in a number of wells in the locality for which the inquiry is to be made. It is not necessary to mention the devices used for the purpose; it may be proper, however, to suggest caution in the use of material that will not give false results. Care should also be taken lest peculiar changes in the water-level of some wells, due entirely to some local condition, be used to interpret the general water-level of the district.

The *rôle* played by soil-moisture in connection with the etiology of disease, has assumed fresh importance since the results of Bowditch, Buchanan, Pettenkofer and others have been given to the world. A humid soil, simply as such, is proverbially unhealthy, and marshy and water-logged lands have long been recognized, the world over, as a cause of paroxysmal fevers. It is known that the exhalations from moist soils impregnated with organic matter (in a state of decomposition), exert a deleterious influence upon the health. Contaminated soil-water flowing into wells from which the supply for drinking purposes is obtained, is also accepted as an agency by which disease is frequently produced. But it is only recently that investigations have been made, which conclusively prove that humidity of the soil is an important factor in the production of diseases, immensely destructive of life, which have hitherto been supposed to be only slightly, or not at all, affected by this cause. Dr. Bowditch[1] has shown that this characteristic of the soil is one of the primal causes of consumption in Massachusetts, and perhaps in New England; and Dr. Buchanan, by a series of independent observations, has arrived at a similar conclusion, namely, "that wetness of the soil is a cause of phthisis to the population living upon it," and he adds that this proposition "may now be affirmed generally, and not only of particular districts."

Enteric fever is another disease that may be mentioned in this connection. The hypothesis that its causation is connected with certain obscure changes in the soil which bear a fixed relation to the fluctuations in the level of the ground-water has the support of many competent observers, especially in Germany. Foremost among these is Dr. Pettenkofer, whose investigations of the subject in connection with the soil of Munich have become celebrated. While the facts brought forward to show the relationship between the state of the water-level and the prevalence of enteric fever seem to clearly indicate that it is more than casual in some districts where long-continued observations have been made—in that of Munich, for example; in other districts, where similar inquiries have been made, the relationship has been found to be wanting.

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[1] Med. Communications of the Mass. Med. Soc., Vol. X., No. 2, Boston, 1862.

A similar theory has been advanced with respect to the causation of cholera, and striking examples have been furnished to prove the correctness of the view. Neither of these particular theories has been generally accepted by the medical profession. Nevertheless, it must be admitted, that, if not in the particular mode which the advocates of the "ground-water theory" would have us accept as the exclusive one, a wet soil is a significant element in the causation of these diseases, inasmuch as it favors the decomposition of excremental and other filth, so readily absorbed by moist, porous soils, the products of which infect the air and mingle with and pollute the ground-water, which in turn contaminates the water of wells and springs.

Water in the soil is injurious to health,—by the effects of dampness, simply as such; by favoring the decomposition of organic matters in the soil, and the evolution of unhealthy effluvia; and by the effect of the ground-water itself through its liability to become polluted, in which case it is dangerous to health, especially when it is the source of supply of water in wells and springs used for drinking purposes. The effects of a damp soil are presented in the following conclusions laid down in the English Sanitary Report for 1852: "1. Excess of moisture, even on lands not evidently wet, is a cause of fogs and damps. 2. Dampness serves as a medium of conveyance for any decomposing matter that may be evolved, and adds to the injurious effect of such matter in the air; in other words, the excess of moisture may be said to increase or aggravate excess of impurities in the atmosphere. 3. The evaporation of the surplus moisture, lowers temperature, produces chills, and creates or aggravates the sudden and injurious changes of temperature, by which health is injured."

Moisture is an essential element in the process of organic decomposition in the soil, by which those mysterious products are evolved, which are known by their effects to be injurious to health. Heat and a moderate supply of air are also necessary factors in the establishment of the process. "The ground-water is presumed to affect health by rendering the soil above it moist, either by evaporation or capillary attraction, or by alternate wettings and dryings." (Parkes.) The changes in its level furnish the best means we have for determining the variations in the moisture of the soil. "It is generally admitted," says Dr. De Chaumont,[1] "that a persistently low ground-water, say fifteen feet down or more, is healthy; that a persistently high ground-water, less than five feet from the surface, is unhealthy; and that a fluctuating level, especially if the changes are sudden and violent, is very unhealthy." The constitution of the ground-water is influenced by the character of the soil and the substances found in and upon it. And this is an important fact, since the ground-water is the source of supply of wells and springs.

The indications presented by the foregoing considerations may be summarized as follows: 1. In the construction of dwellings, to provide

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[1] Lectures on State Medicine, London, 1875, p. 100.

the most efficient means for excluding dampness from the foundation walls and basement floors.

2. To keep the soil free from impurities of whatsoever nature.

3. To render the soil drier by underground drainage and by opening the outflow.

Whatever may be the character of the soil, it is always safe and advisable to underlay the entire foundation of a house with a layer of concrete, as shown in Fig. 3. A damp-proof course should be constructed in the walls just above the surface of the ground, to prevent moisture from striking upward by capillary attraction. Various kinds of material have been used to form damp-courses. They have been made of slate embedded in cement, of layers of sheet lead, and of layers of asphalt. Enamelled bricks have also been used with advantage. But the best article thus far devised is the vitrified stoneware tile, which is made in different patterns and thicknesses, and perforated in order to permit free access of air between the floor and the ground. A number of these tiles are shown at Fig. 5. These damp-courses should be laid through the entire thickness of the walls, and at a few inches above the ground, or sufficiently high to avoid the effects of splashing from rains. Figs. 4 and 8 represent damp-proof courses in position. The condition of the walls of *old* houses may be greatly improved, and the houses rendered more habitable, by cutting out the wall and inserting damp-courses.

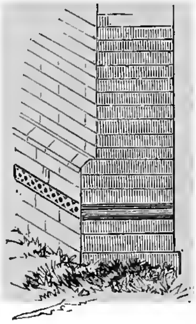

FIG. 4.

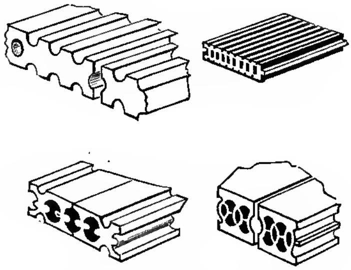

FIG. 5.

FIG. 4.—Wall with damp-proof course of vitrified stoneware tiles (Eassie).
FIG. 5.—Vitrified stoneware tiles.

Additional protection against dampness may be secured by interposing well-drained areas between the ground and the basement walls, as shown at Fig. 3. This is decidedly the best plan, but where it cannot be adopted hollow walls, or the so-called "dry areas," are recommended. These are constructed by leaving an air-space between the basement-wall and a second or area wall, which joins the main wall just above the ground-level, as seen at Fig. 6. Another plan, highly recommended by Mr. Eassie, consists in the use of vitrified stoneware tiles, such as are designed for flat damp-courses, placed perpendicularly so as to form a wall-casing up to the ground-floor. As represented by Fig. 7, the casing, which forms a sort of supplementary wall, is bonded to the brickwork of the house by the same kind of stoneware tiles. The requisite support may be given to the outside wall by using bonding bricks, or wall-ties made of impermeable material, such as the tiles just described. Patent stoneware bonding-bricks are much used in England, and answer a very useful purpose. The spaces between the walls should be ventilated, and the bottom of the area well concreted and drained. Hollow walls furnish the best proof against dampness from the water-saturated earth, and the splashings of heavy rains. They afford the very best means of preventing the moisture from the outside walls of buildings from passing to the inside, and may be used with advantage wherever buildings stand in an exposed situation. The manner of constructing such a wall is illustrated at Fig. 8. The bonding brick for connecting the twin walls is the device of Mr. Jennings, who claims for it this advantage, that it will prevent the passage of moisture.

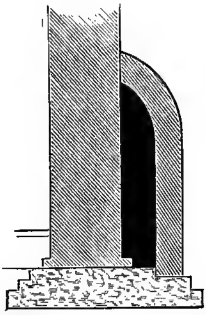

FIG. 6.—Dry area wall (Eassie).

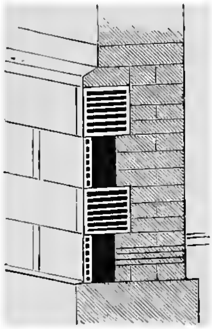

FIG. 7.—Wall-casing of vitrified tiles (Eassie).

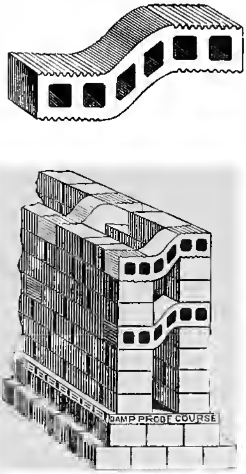

FIG. 8.—Hollow walls and Jennings' patent bonding bricks.

In addition to these measures to prevent dampness it will often be necessary to drain the site of a building. Deep drainage not only removes the bad effects of dampness, but it is also of advantage by aërating the soil so as to enable it to perform its functions of oxidizing the injurious products of decomposition. By the free circulation of air in the soil the work of natural purification is promoted. Drainage aids the process by removing the water from the pores of the soil, and by facilitating the entrance of air which is required for oxidation.

Clay soils possess the property of retaining moisture, which it is difficult to overcome, even by well-devised plans of drainage. The flat, sandy soils, that in some places skirt the borders of the sea, are always moist at a little distance below the surface, on account of the nature of the locality, and for the same reason underground drainage is impracticable. Such soils—in fact, all damp soils which cannot be properly drained—should, as a rule, be avoided altogether; but when they are built upon, the precaution should always be observed to elevate the dwelling sufficiently above the surface of the ground to permit a free circulation of air.

The means of preventing the entrance of impurities into the soil are pointed out in another place.

Drainage of the Soil.

The drainage of the subsoil—that is, the lowering of the water-level to a proper depth beneath the surface, and the removal of all excess of moisture—may be considered with respect to individual houses, to the sites of towns and cities, and in relation to lands, marshes, and malarious districts.

Whatever responsibility may devolve upon the local or state authorities in a matter of such vital importance to the public health, and however excellent may be the system devised and executed for rendering the soil dry and wholesome, it is judicious and advisable that the individual householder should give his attention to the condition of the soil under and around his dwelling. Unless the ground be comparatively free from moisture, the site of the dwelling and the surrounding soil should be thoroughly drained by means of ordinary land-drainage pipe. The drains should be placed some distance from the building, if the soil be a free and porous one. The more retentive the soil is of moisture, the greater will be the number of drains required ; but, in ordinary soils, a single well-laid drain will answer the purpose. It may be necessary, in extreme cases, to lay the drain round the foundation of the building, especially when located on springy or clay soils. The precaution should be observed to place it at a considerable distance below the foundation, and to construct it in such a manner as to avoid any possible risk to the superstructure. On this point the advice of a sanitary engineer should be sought. "This drain may be made of gravel or broken stones, but ordinary land-drainage tile with open joints is usually cheaper and always better, especially as preventing the ingress of vermin.

"For the largest private house, the smallest sized land-drain tile will be sufficient. If the soil is unduly wet, at any season, similar drains should cross the cellar at intervals of not more than fifteen feet. All of these drains should have a slight but continuous fall toward the outlet, and should be securely covered by having earth well rammed over them, the whole cellar bottom being then coated with concrete. For small houses, where cobble-stones or gravel are plenty, if the foundation rests on a layer of this porous material a foot or more deep, and if a good outlet be provided at the lowest point, the tile is not needful." (Waring.)

The sites of houses in the country should always be selected with reference to their freedom from dampness. If the soil be not dry, it can be rendered so by the laying down of drain-tiles, as has just been pointed out. Dr. Bowditch has shown how common is the neglect of this important feature of the soil, and furnishes numerous examples to prove that soil-moisture has been the prime factor in determining the peculiar forms of disease to which the inmates of certain houses in the country have always been more or less subject, "that some houses may become the foci of consumption, when others but slightly removed from them, but on a drier soil, almost wholly escape."

The deep drainage of "made-ground," especially when the site is used for habitations, should not be neglected. It is a common error to suppose that the filling up of sunken lots, often containing water, and of low, wet lands in the environs of towns, preparatory to the extension of building operations, removes the injurious influences of the wet subsoil. Small streams are often covered up in this way without providing facilities for the outflow of the water. Filling in these depressions in the ground does not alter the water-level, nor remove the effects of dampness; on the contrary, unless ample drainage be provided, these new-made sites are almost invariably dangerous locations for habitations. The surface may be covered with solid material, but the soil beneath still remains saturated with water.

The channels of watercourses should be kept free by means of drain-pipes made pervious to water. Basins of water may be drained by boring through the impervious stratum and filling in the wells with broken stones; or ordinary drain-tiles may be used to carry off the water by a free outlet.

An investigation, suggested by the prevalence of diphtheria in New York in 1872, led to the discovery that many of the old watercourses and natural springs had been filled in, years before, without making provision for free drainage of the soil. And as the disease seemed to be especially prevalent along the line of these old watercourses, it was inferred that defective drainage of the subsoil was concerned in its causation. Be this as it may, it was generally conceded that the condition of the soil revealed by this inquiry was injurious to the public health.

Two-thirds of the deaths that occurred in Dublin during the epidemic of cholera in 1866 took place, according to Mapother,[1] on or close to the sites of old watercourses that had been converted into sewers, or filled up with mud.

The extensive works for draining the subsoil, undertaken in all civilized countries for the advancement of agricultural projects, have incidentally exerted a very beneficial influence upon the public health. The construction of sewers for the purpose of removing the surface-water, and the liquid refuse from houses, has had the important effect of diminishing mortality, which effect is largely attributable to the drying of the subsoil, by lowering the ground-water. The investigations of Dr. Buchanan, with the object of determining the influence of the sewerage works of England on the public health, have demonstrated this fact beyond a doubt. The following table shows the general improvement which has taken place in the health of twelve towns, principally in consequence of drainage operations:

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[1] Lectures on Health, p. 487.

TABLE SHOWING THE IMPROVEMENT IN THE PUBLIC HEALTH BY SANITARY WORKS.[1]

Name of place.	Population in 1861.	Average mortality per 1,000 before construction of works.	Average mortality per 1,000 since completion of works.	Saving of life, per cent.	Reduction of typhoid fever, rate per cent.	Reduction in rate of phthisis, per cent.
Banbury...	10.238	23.4	20.5	12½	48	41
Cardiff....	32.954	33.2	22.6	32	40	17
Croydon...	30.229	23.7	18.6	22	63	17
Dover.....	23.108	22.6	20.9	7	36	20
Ely	7.847	23.9	20.5	14	56	47
Leicester ..	68.056	26.4	25.2	4½	48	32
Macclesfield	27.475	29.8	23.7	20	48	31
Merthyr ...	52.778	33.2	26.2	18	60	11
Newport...	24.756	31.8	21.6	32	36	32
Rugby	7.818	19.1	18.6	2½	10	43
Salisbury ..	9.030	27.5	21.9	20	75	49
Warwick ..	10.570	22.7	21.0	7½	52	19

The advantages resulting from deep drainage of the subsoil of towns are so manifest that there can no longer be any doubt as to the duty of the local authorities to construct works in all urban districts with special reference to drying and aërating the subsoil. How best to construct such works so as to secure every sanitary advantage, without incurring too great an expense, has been a difficult problem to solve. It is a common practice to construct sewers of porous material, such as brick, with their inverts laid dry, the effect of which is to allow the moisture in the surrounding soil to readily pass off by the channel of the sewer with the sewage. But this result is not constant; for if the water in the surrounding soil is lowered, from whatever cause, the sewage, which should be confined within the sewer, will escape into the subsoil, with its attendant evil consequences. In some localities, with peculiar physical conditions, it may be necessary to admit the soil-water into the sewer; but only where it can be demonstrated that the flow into the sewer is a constant one. In such cases there is but little risk of the escape of sewage into the adjacent soil. Nevertheless, as a rule, sewers should be made as nearly water-tight as possible; and whenever it is necessary to drain the subsoil, independent works should be constructed for the purpose—independent in so far as a separate and distinct channel is provided for the soil-water; but, in most instances, they may be laid in the same trench with the sewer and constructed at the same time.

Systematic drainage and systematic sewerage should be complemen-

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[1] Latham: Sanitary Engineering, p. 2.

tary operations. The one cannot properly include, nor supply the place of, the other.

Various plans have been suggested to accomplish this object. One of these, as represented by Fig. 9, consists in making the sewer in two parts, the upper one as nearly water-tight as possible for sewage, and the lower one of porous material with open joints, for the removal of the soil-water. The objection to this plan is, that the sewage will escape through the joints, which it is difficult, in practice, to keep thoroughly tight, and thus pollute the water in the drain. This objection is not a serious one, unless the soil-water is collected and removed for other objects than that of simply drying the subsoil.

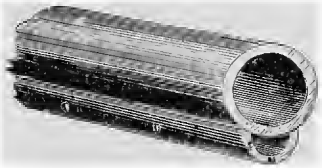

Fig. 9.—Combined sewer and drain.

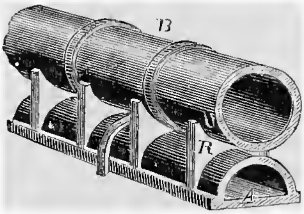

Fig. 10.—Sewer-pipe and subsoil-pipe of Huddersfield.

A modification of this plan is the combined sewer-pipe and subsoil-pipe of Huddersfield, illustrated by Fig. 10. The subsoil-pipes (A) are laid at the bottom of the trench, and, by their peculiar shape, afford a good foundation for the sewer (B) which lies above them, supported on rests (R). The subsoil water enters at the loose joints of the drain-pipe (A), and is carried off by a separate conduit, while the sewage is removed by the water-tight sewer above it. Should the sewer leak, the escaping liquid will be taken up by the subsoil pipe, which mode of disposal will be objectionable if the soil-water collected in this way is to be brought into special use. It is claimed for this system that the joints of the sewer-pipe can be laid in cement and made water-tight, and that it is "the only one which permits a dry foundation for drainage-pipes in swampy ground."

The objections urged against these methods may be overcome by constructing independent conduits in the same trench, but detached from one another, so that the one can in no manner detract from the utility of the other. Of this description is the plan[1] of subsoil drainage introduced by Wiebe and Latham in constructing the sewage-works of Dantzic, and which they assert secures all the advantages required in carrying out works of this character. The method adopted is shown at Figs. 11 and 12.

"The sewer proper, S, whether constructed of brickwork or earthenware pipes, was first laid in the trench and covered over with a layer of clay puddle, C, which was well and carefully rammed into position. In

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[1] Latham: Sanitary Engineering, Chicago, 1877, p. 51.

some cases, over the clay, several feet in depth of the trench were filled in with selected gravel, shown by G, Fig. 11, which is perfectly pervious, and upon this gravel the ordinary materials excavated, E, were placed; the arrangements for the discharge of the subsoil water were so managed that every lateral line of sewer is provided with a free discharge into the river. In other cases the method shown in Fig. 12 was adopted after the insertion of the sewer and its covering of clay; two lines of ordinary agricultural land-drains were laid on each side of the trench, so as to communicate directly with the surface-water streams of the district. Subsoil drainage may be carried out in most places in the way delineated in Fig. 12, care being taken that the sewers are rendered impervious, so as to prevent the escape of sewage, porous drains being laid immediately above them; the subsoil water may be conveyed to any convenient point, and air may be admitted freely into the subsoil, while the expense of the work is trifling compared with the advantages to be gained."

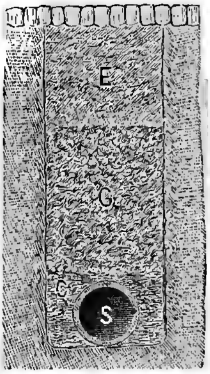

Fig. 11.

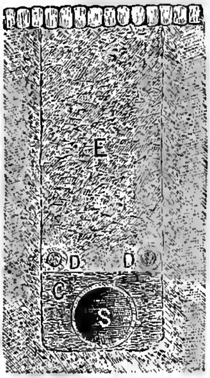

Fig. 12.

In some cases, it may be advisable to lay the subsoil drains in connection with the sewer; in others, it may be better practice to have them constructed without any reference whatever to the situation of the sewer. The selection of the plan must be determined by circumstances which are connected with the locality.

It is frequently necessary in building sewers to place temporary drains under their beds, in order to allow the brickwork to set before being exposed to the action of water. By a very trifling increase in the cost such temporary works may be made permanent, and this expense will be amply repaid by an improvement in the public health.

In towns having a scanty water-supply, and, in fact, in all towns, use may be made of the water collected in subsoil drains as a means of flushing, for which purpose reservoirs can be made, and connections with the sewers arranged, so as to thoroughly flush them at stated intervals.

Practically, sewers are not water-tight, as at the junctions with private communicating sewers, and even through the walls of sewers as commonly constructed, there must be more or less influx of water from the soil. The disadvantages of a pervious sewer have already been alluded to; in the absence of a separate system of subsoil drainage, the advantages are: the lowering of the ground-water and the drying of the soil, which results have had a beneficial effect upon the public health, as has been shown in the case of a number of English towns in which such sewers have been introduced.

The influence of humidity of the soil on diseases usually affected by this condition, seems to be very much modified in localities with a stratum through which salt water freely percolates, such as the flat, sandy sites of some seaside towns. Investigations have determined this point, at least so far as phthisical complaints are concerned. The principal reason assigned is the free circulation of the water through the pores of the soil, caused by the alternate rise and fall of the tide, whereby stagnation of water and changes in the soil, which would otherwise occur, are prevented. The peculiar character of the water and the conditions of the atmosphere may have some modifying influence. In such places deep subsoil drainage is impracticable, even by the aid of pumping. The alternative suggested is to raise the lower floor of the house a considerable distance above the surface of the ground, that air and sunlight may do their beneficent work.

The drainage of lands purely for sanitary reasons has been a lamentably infrequent occurrence, but operations undertaken strictly in the interests of agriculture have been carried out in all civilized countries from the remotest period.[1] Incidentally, such works have been of the greatest value in improving the public health. The evidence that could be adduced to corroborate this statement is complete and conclusive. A reference to the voluminous reports on this subject, published within recent years by authority of the government of England, will be sufficient to satisfy the most sceptical on this point. Districts, in which, formerly, malarial diseases seriously affected the health of the inhabitants, have become comparatively salubrious, these diseases having steadily decreased in frequency, and become of milder type, since the introduction of improved drainage works.

We need only refer to the vast fen lands in Norfolk, Lincolnshire, and Cambridgeshire, counties in which intermittent and remittent fevers of severe type were, at one time, very prevalent. Since the improved drainage of these districts, malarial fevers have become comparatively rare and mild of form. In other counties the same decline in malarial diseases has been noticed to have been simultaneous with, and subsequent to, the

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[1] One of the most memorable examples of insalubrity depending on conditions of the soil is that of the celebrated Pontine Marshes in the Campagna of Rome. Fabulous sums of money have been expended in endeavors to reclaim these lands and render them healthful, an effort being made in this direction as early as 312 B.C., but permanent results have never been obtained. At the present day the subject has been revived, and projects have been suggested whereby this area of waste land may be rendered cultivable and salubrious.

carrying out of extensive drainage operations. And so as regards England generally, it may be safely asserted that these diseases "have been steadily decreasing, both in frequency and severity, for several years, and this decrease is attributed, in nearly every case, mainly to one cause—improved land drainage."[1]

The same results have followed similar operations in other countries. In this country evidence is not wanting to prove that increasing salubrity has almost universally followed skilful and efficient drainage of the land. The instances on record are less conspicuous than those above alluded to, and less numerous, but they would be greatly multiplied were the same effort made as in England to collect this important testimony. A recent sanitary inquiry, conducted by Dr. Bowditch, has elicited valuable information in regard to this country, some of it bearing directly upon the present subject. An instance is reported by Dr. Breed,[2] of the satisfactory sanitary results of drainage of swamp-lands in Bureau County, Illinois (completed within a few years), which had always been unproductive and a cause of the unhealthy condition of the neighborhood. "The result is that about thirty-six thousand acres of these inundated or swamp-lands have been either greatly improved or quite redeemed. Twenty thousand acres, hitherto of little or no value, have been converted into excellent pasture and meadow lands, while no inconsiderable portion has been rendered good tillage land. Thus, by these means, thousands of acres, once nearly covered with water, swampy, and grown up and covered with reeds, brakes, and coarse grass, interspersed with knolls covered with small trees and tangle wood, the favorite haunts of water-fowls, reptiles, and musk-rats, sending forth over the adjacent country a noisome and pestilential miasm, have become converted into dry land, rich pastures, and meadows, where vast herds of cattle may be seen cropping the rich, luxuriant grasses. As a natural sequence, although it does not appear to have had any influence in inducing 'the powers that be' to do the work, the health of the people in these townships has been incidentally improved." This same observer says, that "as the county becomes improved, settled, and generally cultivated, the diseases prevalent have undergone a change, and some of them, that were a terror to the early settlers, are now but seldom heard of, or seen." Similar results are reported[3] from Michigan, New York, and other States. The Transactions of the State Medical Societies contain much information on this subject from various parts of the country.

In furthering projects for land drainage health has seldom been the object aimed at, except in the vicinity of towns, where the interests of a large number of persons are directly concerned, and the capital is available for the purpose.

Private enterprise, although it has accomplished valuable results, has

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[1] Dr. Whitley's Report to the Board of Health, England, 1864.

[2] Bowditch: Hygiene in America, 1877, p. 159.

[3] Ibid., 1877, pp. 177, 178, 205, etc.

often failed for want of co-operation, and on account of the impracticableness and uselessness of any attempt to reclaim and render salubrious a portion of a district while the remainder of it still possesses all the undesirable features of insalubrity. Nothing short of systematic improvement of the whole district will secure the results desired, and this can only be accomplished by united effort. It is evident, therefore, that drainage operations (as affecting the general health of the people) should be undertaken by State authority. It is needless to refer, except very briefly, to methods adopted for draining the soil to promote health, since they are essentially the same as those in use for the agricultural improvement of the land.

Open drains are not suitable for drying the body of the soil, and are not advisable except in very special cases. They may be resorted to as a temporary expedient, and are sometimes used as auxiliaries to a well-devised plan of drainage. Of the various kinds of closed drains in use none is comparable to the tile-drain, and, of this variety, the "pipe or round tile and collar" is the very best tile thus far devised. The object of drainage is the removal of all surplus water from the soil, from whatever source, and the rendering of the soil, to a considerable depth, dry, more porous, and well aërated.

Deep drainage is now advocated as the best for agricultural purposes —a depth of four feet not being considered too much. It is certainly the most suitable when the object is the improvement of health. The lower the water-table, *cæteris paribus*, the more salubrious will be the soil.

Large tracts of land are sometimes water-soaked and unhealthy on account of the peculiar conformation of the underlying impervious strata.[1] By breaking through these formations so as to afford an outlet, a settling

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[1] Says a recent letter from Rome, the monks of La Trappe have lately discovered "the means of making the vast Roman Campagna healthy, a work that has baffled all the governments from Romulus to Victor Emanuel or King Umberto. The malaria (evil or bad air) is well known to geologists. The soil of the Campagna has but little depth. Under it lies a stratum of tufa; in some places this tufa is two metres deep. Under this tufa is other volcanic material, equally hurtful to vegetation. Thus there is no subsoil, and no chance for circulation of water and air. When the heavy rains fall, the water rests on the tufa, and generates unhealthy mists. When the droughts come, the soil is baked to ashes. The wise, good, industrious Trappists began on that very unhealthy land of the Three Fountains, first with the Eucalyptus raising, and made the place comparatively healthy. Lately they have tried, with success, a most remarkable experiment. They have bored the tufa, at different distances, a metre and a half deep; in these holes they have placed dynamite, and by electric conductors, exploded the volcanic strata. A dumb rumbling is heard, a little elevation of the ground is seen, in some places the earth is thrown out a short distance. In eight days' time they found a subsoil for a large space of ground, and made it both susceptible of culture and healthy. The expense is about 600 lire for every hectare (2 acres, 1 r. 35 p.). Thus these simple, busy Fathers of La Trappe, have done the useful work that lay before them, and by that have solved a problem as old as Euclid, and hitherto as fatal as the Sphynx. Their silent labors will give health to future generations, and cover with luxuriant fields of grain the vast Agro Romano."—*Med. and Surg. Reporter*, Nov. 9, 1878, p. 415.

of the imprisoned water into the looser soil below gradually takes place, and the causes which render the soil uncultivable and deleterious to health are removed.[1]

Lands that are subject to occasional overflow, whether by tides or by freshets, require drainage, which, to be complete, involves the construction of embankments, or works to restrain the water and prevent inundations.

Swamps and bogs, so frequently the source of miasmatic effluvia, should be made dry by some one of the methods for drainage, and where this is impracticable, it will be advantageous to health to permanently cover them with a moderate sheet of water.[2]

Salt marshes, such as are found along the Atlantic coast of this country, are frequently the breeding places of malarial poison. Such lands, when reclaimed, are exceedingly valuable for the uses of agriculture, and when near towns, or inhabited districts, should be drained and improved for sanitary reasons alone, though it is demonstrable that the work would be otherwise advantageous and remunerative. A conspicuous example of such lands is furnished by the Hackensack meadows close to the city of New York. Thousands upon thousands of acres of land, containing all the elements of fertility, that could be made productive and salubrious, are here abandoned to the inroads of the sea, and suffered to lie in dreary waste, unproductive, and a menace to the health of the surrounding inhabitants.

To reclaim these marshes, the sea must be excluded by dykes or embankments, the surface-water from the uplands diverted into a proper channel of outlet, and the rainfall and soil-water removed by the use of automatic valve-gates, or by pumping. Formerly the wind was the motive power; but, except for small tracts, steam-power is the best, most practicable, and the most certain means of getting rid of the water.

In Holland and in the English Fens, steam-pumps are fast superseding pumps driven by the action of the wind.

The soil may be rendered drier and its sanitary condition greatly improved by opening the outflow of the water.

Obstructions in streams and rivers should be removed, so as to afford the water a free passage to the ocean, and thus prevent the overflow of lands, which produces a condition of the soil favorable to the production of miasm. The outfalls of rivers become blocked up by deposits of silt,

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[1] Bishoff states that this mode of draining the subsoil, by means of boring, was successfully practised as early as the time of King René, in the first part of the fifteenth century, on the plain of Paluns, near Marseilles. Physikalische Geographie, p. 288.

It is on this same principle that wells are often constructed through tenacious layers of the soil until a stratum of gravel is reached, through which water will readily pass off. Privy-wells excavated to a porous soil, though constantly used for many years, will remain dry; the practice, however, is a bad one.

[2] "Beecher has related several cases in which this plan was successfully adopted, and Empedocles is said to have delivered the Salentini from dangerous exhalations, to which they were subject, by conducting into their marshes two neighboring streams." Dunglison's Hygiene, p. 102.

both from the river and from the sea, which retard their flow, and cause their waters to spread over the low-lying lands by which they are bounded.

The regulation of rivers by altering and deepening their channels, removing obstructions, constructing embankments, etc., with the object of providing a free and unobstructed flow of water, is exceedingly important in its influence upon the outflow of water from lands included in their areas of drainage. As illustrative of the beneficial effects of the regulation of watercourses, the river Theiss, in Hungary, may be mentioned, along the lower course of which stream not less than 250,000 acres of pestilential and wholly unproductive marsh have been converted into a healthful region of the most exuberant fertility.[1]

3. *Solid Constituents of the Soil.*

The solid constituents of the soil may be studied with respect to their chemical composition, and to their geological and topographical conditions as influencing the configuration of the surface and the conformation of the underlying structures, and the constitution of the soil and of its rocky substrata. The latter bear directly upon the movement of water and air in and over the ground, and determine and control both artificial and natural drainage. A knowledge of these natural features of the earth's crust is essential to a successful sanitary survey of a district.

The solid constituents of the soil consist of mineral, vegetable, and, to some extent, of animal substances, found in various states of combination, and, as such, classified according to some predominant characteristic or peculiar arrangement of the parts. They appear in the form of rocks of various structure, texture, composition, and conformation, or in the form of purely mineral accumulations, such as clays, sands, gravels, and other rocky débris, the result of decay and disintegration of rocks by the influence of air, water, heat, and other forces; or, in the form of mineral accumulations with an admixture of organic matter, both vegetable and animal.

"But whatever may be their composition or texture, soils, geologically speaking, are mainly of two sorts, *soils of disintegration*, arising from the waste and decay of the immediately underlying rocks, together with a certain admixture of vegetable and animal débris; and *soils of transport*, whose ingredients have been brought from a distance, and have no geological connection with the rocks on which they rest. Under the former are comprehended such as arise from the disintegration of limestones, chalks, traps, granites, and the like, and which are directly influenced in their composition, texture, and drainage, by the nature of the subjacent rocks from which they are derived. Under the latter are embraced all drift and alluvial materials, such as sand, shingly débris, miscellaneous silt and clay which have been worn from other rocks by meteoric agencies, and transported to their existing positions by winds, waters, or ancient

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[1] Marsh: The Earth as Modified by Human Action, 1874, p. 436.

glacial agencies. Besides these there are also soils of organic origin, such as peat-earths, and vegetable mould or *humus*, which is, to a great extent, also of animal origin or elaboration. Indeed in all superficial soils, there is a certain amount of vegetable and animal matter—the decay of plants, the droppings of animals, the exuviæ of insects, the casts of earth-worms, and the like."[1]

Mineral Matters.

The mineral constituents of the earth's crust are very numerous; some of them are very abundant,[2] but they are not all of equal importance. They are found in distinct masses having well-defined characteristics, and present a certain order of arrangement. They determine the contour of the ground, and by their physical characteristics radically affect the salubrity of a locality. The relation to health of some of the more common rocky formations and soils has been very concisely presented by Dr. Parkes, from whose work the following extract is taken:[3]

"*The Granitic, Metamorphic, and Trap Rocks.*—Sites on these formations are usually healthy; the slope is great, water runs off readily; the air is comparatively dry; vegetation is not excessive; marshes and malaria are comparatively infrequent and few impurities pass into the drinking-water. When these rocks have been weathered and disintegrated, they are supposed to be unhealthy. Such soil is absorbent of water; and the disintegrated granite of Hong-Kong is said to be rapidly permeated by a fungus; but evidence as to the effect of disintegrated granite or trap is really wanting.

"In Brazil the syenite becomes coated with a dark substance, and looks like plumbago, and the Indians believe this gives rise to 'calentura,' or fevers. The dark granitoid or metamorphic trap, or hornblendic rocks of Mysore, are also said to cause periodic fevers; and iron hornblende especially was affirmed by Dr. Heyne of Madras to be dangerous in this respect. But the observations of Richter on similar rocks in Saxony, and the fact that stations on the lower spurs of the Himalayas on such rocks are quite healthy, negative Heyne's opinion.

"*The Clay Slates.*—These rocks precisely resemble the granite and granitoid formations in their effect on health. They have usually much slope; are very impermeable; vegetation is scanty; and nothing is added to air or to drinking-water. They are consequently healthy. Water, however, is often scarce; and, as in the granite districts, there are swollen brooks during rain, and dry watercourses at other times swelling rapidly after rains.

"*The Limestone and Magnesian Limestone Rocks.*—These so far resemble the former, that there is a good deal of slope, and rapid passing off of water. Marshes, however, are more common, and may exist at great heights. In that case the marsh is probably fed with water from some of the large cavities, which, in the course of ages, become hollowed out in the limestone rocks by the carbonic acid of the rain, and form reservoirs of water. The drinking-water is hard, sparkling, and clear. Of the various kinds of limestone, the hard oolite is the best, and magnesian is the worst; and it is desirable not to put stations on magnesian limestone if it can be avoided.

"*The Chalk.*—The chalk, when unmixed with clay and permeable, forms a very

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[1] Page: Economic Geology, Edinburgh and London, 1874.

[2] The minerals constituting the great bulk of the earth are—quartz, felspar, mica, limestone, hornblende, serpentine, gypsum, talc, and oxide of iron. Tenuey's Geology, p. 26.

[3] Practical Hygiene, pp. 339-341.

healthy soil. The air is pure, and the water, though charged with carbonate of lime, is clear, sparkling, and pleasant. Goitre is not nearly so common, nor apparently calculus, as in the limestone districts. If the chalk be marly, it becomes impermeable, and is then often damp and cold. The lower parts of the chalk, which are underlaid by gault clay, and which also receive the drainage of the parts above, are often very malarious; and in America, some of the most marshy districts are on chalk.

"*The Sandstones.*—The permeable sandstones are very healthy; both soil and air are dry; the drinking-water is, however, sometimes impure. If the sand be mixed with much clay, or if clay underlies a shallow sand-rock, the site is sometimes damp. The hard millstone grit formations are very healthy, and their conditions resemble those of granite.

"*Gravels* of any depth are always healthy, except when they are much below the general surface, and water rises through them. Gravel hillocks are the healthiest of all sites; and the water, which often flows out in springs near the base, being held up by the underlying clay, is very pure.

"*Sands.*—There are both healthy and unhealthy sands. The healthy are the pure sands, which contain no organic matter, and are of considerable depth. The air is pure, and so is often the drinking-water. Sometimes the drinking-water contains enough iron to become hard, and even chalybeate. The unhealthy sands are those which, like the subsoil of the Landes, in Southwest France, are composed of siliceous particles (and some iron), held together by a vegetable sediment.

"In other cases sand is unhealthy, from underlying clay or laterite near the surface, or from being so placed that water rises through its permeable soil from higher levels. Water may then be found within three or four feet of the surface; and in this case the sand is unhealthy, and often malarious. Impurities are retained in it, and effluvia traverse it. In a third class of cases the sands are unhealthy, because they contain soluble mineral matter. Many sands (as, for example, in the Punjab) contain much carbonate of magnesia and lime-salts, as well as salts of the alkalies. The drinking water may thus contain large quantities of sodium chloride, sodium carbonate, and even lime and magnesian salts, and iron. Without examination of the water it is impossible to detect these points.

"*Clay, dense Marls, and Alluvial Soils generally.*—These are always to be regarded with suspicion. Water neither runs off nor runs through; the air is moist; marshes are common; the composition of the water varies, but it is often impure with lime and soda salts. In alluvial soils there are often alternations of thin strata of sand, and sandy impermeable clay; much vegetable matter is often mixed with this, and air and water are both impure. Vast tracts of ground in Bengal, and in other parts of India, along the course of the great rivers (the Ganges, Brahmapootra, Indus, Nerbudda, Krishna, etc.), are made up of soils of this description; and some of the most important stations even up country, such as Cawnpore, are placed on such sites. The deltas of great rivers present these alluvial characters in the highest degree, and should not be chosen for sites. If they must be taken, only the most thorough drainage can make them healthy. It is astonishing, however, what good can be effected by drainage of even a small area, quite insufficient to affect the general atmosphere of the place; this shows that it is the local dampness and the effluvia which are the most hurtful.

"*Cultivated Soils.*—Well-cultivated soils are often healthy; nor at present has it been proven that the use of manure is hurtful. Irrigated lands, and especially rice-fields, which not only give a great surface for evaporation, but also send up organic matter into the air, are hurtful."

Organic Matters.

The organic matter in the soil is both *vegetable* and *animal*, the former being found in much larger proportion. Many of the strata which form the rocky crust of the earth are largely composed of the remains of plants and animals, the work of past ages. Vegetable and animal life still exerts a great influence upon the physical condition of the soil, though there may be no perceptible alteration in the terrestrial surface.

The vegetable matter found in the soil is partly derived from the decay of plants in and upon the soil—a process which is continually in operation, and which is an important agency in the formation of soils. Vegetable débris are borne by the wind over the surface, mingled with the earth, and deposited in hollows and depressions; they are carried beneath the surface by rains, and spread over the low regions bordering on large water-courses as a constituent of alluvium, and are deposited by the action of water in the silt formations upon the banks and at the mouths of rivers. Near the mouth of the Mississippi, sand, gravel, and vegetable matter have accumulated in alternate layers to a great depth.[1]

It may be deposited in and upon the soil, and be so disposed with regard to the soil and other surroundings as to give rise to conditions acting injuriously upon health.

Peat is a deposit of vegetable origin produced in cool countries in swamps and moist situations. Mosses, rushes, grasses, heaths, and other marsh plants, principally contribute to its formation. Millions of acres of peat occur in the British Islands, varying in thickness from five to thirty feet. North America possesses hundreds of square miles of the same material, from five to twenty feet in thickness.[2] It is found elsewhere in temperate climates.

"Submerged forests" and beds of peat are found along the shores of Great Britain, embedded to a considerable depth in marine clay.[3] The beds of rivers in wooded regions conceal trunks of trees which once floated upon their surface. Drift-wood collects in rafts and becomes water-soaked, and sinks, and the river deposits cover them up. A raft of this kind on the Washita, a river of Arkansas and Louisiana, covers the surface of the river for fifty miles. The immense quantity of wood annually drifted down the Mississippi and its tributaries illustrates the manner in which an abundance of vegetable matter becomes embedded in the river bottom and in submarine and estuary deposits.[4] The soil at New Orleans contains innumerable trunks of trees, in various positions, which had grown in marshes above the level of the sea. The same discovery has been made hundreds of miles up the river Mississippi.[5]

Animal matter, or at least the evidence of its past existence, is found as fossils in nearly all rock formations, and in the form of extensive deposits in various parts of the world. Accumulations of bones and tusks of elephants, mastodons, and other huge pachyderms occur in profusion in

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[1] Tenney's Geology, p. 260.

[2] Page: Economic Geology, Edinburgh and London, 1874, p. 158.

[3] Quart. Journal of Science, etc., No. XIII., N. S., March, 1830, and Geolog. Trans., 1st Series, Vol. 3, p. 383.

[4] Lyell: Principles of Geology, 1858, p. 268.

[5] Ibid., p. 269.

Siberia, particularly near the shores of the frozen ocean,[1] and the skeletons of quadrupeds fill extensive caves in various parts of the world, and form calcareous deposits of considerable magnitude. Animal organisms teeming in the water and in the earth, and existing upon its surface and in the air, during their growth and by their decay, are still contributing important elements to the soil.

The remains of domestic animals [2] and those of man add to the earthy matter coating the globe's surface. The constant admixture of animal matter with the soil, though inconsiderable compared with the bulk of the earth's crust, has an important modifying influence upon the character of the superficial strata.

But it is only under special conditions that the admixture of these substances with the soil is hurtful to man. Nature has provided in the laboratory of the earth, and in the forces of vegetation, a means of resolution of these matters into new products, wisely adapted for absorption and assimilation by plants. Where her laws are disregarded and her processes interfered with, evil results will inevitably follow, unless the loss or hindrance of natural agencies is compensated for by the use of artificial means.

In cities the natural contour and character of the surface of the ground is entirely changed; vegetation is destroyed; the surface is sealed with stone and cement; the natural streams of drainage are ignored, and the subsoil is often converted into a receptacle for rejected matters. The soil is paralyzed and crippled, and utterly unable to perform its natural functions. It is through man's agency that these abnormal conditions exist, and it is through his agency that the remedies must be supplied, and these consist in the introduction of complete systems of sewerage and drainage, and the adoption of every arrangement to secure the utmost cleanliness, and to preserve the soil as pure as possible.

Wherever there is an aggregation of human beings, as in towns, the soil, especially when porous, is apt to be charged with animal matter, particularly human excrement, the most dangerous of all the forms of refuse substances. In long inhabited districts this material accumulates and renders the ground highly impure, and is a principal cause of the unhealthiness of the locality.

The character of the soil is an important feature to be taken into consideration. Some soils, such as those formed of gravel or sand, are structurally adapted for the imbibition and transudation of liquid substances. They act more like filters, as they allow the liquid portions to pass through them, while they retain all the obnoxious, organic matters in their pores.

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[1] Lyell: Principles of Geology, 1858, p. 78.

[2] It is estimated that there were in North America, in 1870, about 160,000,000 of domestic animals, which, if only half a solid foot be allowed to the skeleton and other slowly destructible parts of each animal, would form a pyramid equal in dimension to that of Cheops.—Marsh: The Earth as Modified by Human Action. New York, 1874, p. 81.

Other soils, such as those composed of clay, possess this property in a very slight degree.

There are two principles suggested by what has preceded which should be stringently observed. 1st. To keep the soil about and under our dwellings pure by removing all waste, organic matters as promptly as possible. 2d. To utilize this material in the cultivation of the soil, whereby it not only ceases to be injurious to health, but actually becomes beneficial to man by furnishing a source of revenue.

Vegetation exerts an important influence upon conditions of the soil as well as states of the atmosphere. One of its effects is to modify the extremes of temperature and humidity. Forests shelter the ground to the leeward, and temper the influence of cold or parching winds to a considerable distance beyond their limits. By their mechanical action they impede the currents of wind and lessen the evaporation and refrigeration which such currents produce, and thus tend to equalize temperature. They screen the soil they cover from the effects of solar irradiation, and, in winter, by accumulating large surfaces of snow, and protecting it from melting, exert an important influence upon the temperature and humidity of the ground.

By the shedding of the foliage of trees, and the decay of vegetation, a protective covering is given to the earth, which guards it against extremes of cold and heat. This layer of vegetable detritus has a capacity to absorb and retain the moisture it receives from the atmosphere, which it, in turn, gradually furnishes to the air by evaporation. It also retains and slowly imparts to the earth beneath it, the rain water, which might otherwise rapidly pass over the surface, or sink into the lower strata.

Trees screen the earth from the sun's rays, and thereby hinder the evaporation from its surface. To some extent they intercept the rainfall, which would otherwise come in contact with the soil and be absorbed by it. The roots of trees, by their power of absorption, draw up a large amount of water from the soil. The amount is vastly greater than that derived from the air through the leaves and bark. Most of this moisture is again parted with, principally to the atmosphere, the amount discharged by the roots and consumed in the process of growth being probably inconsiderable. The amount of water evaporated from the surface of leaves during the season of growth is very great. Schleiden[1] estimates the quantity of water evaporated by a tract of woodland to be ten times the amount precipitated on the same area. Pettenkofer,[2] by experiments made upon the living oak, has calculated the amount of evaporation of the oak-tree during the summer months to be eight and one-third times the rainfall upon an area equal to that shaded by the tree. The Eucalyptus Globulus is asserted by Gimbert, from recent observations made in Algeria, to absorb and evaporate twelve times the rainfall. Such being the case, the absorption of moisture by the roots of trees, and its subsequent

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[1] Baum und Wald, 1870, pp. 46, 47.

[2] Parkes' Hygiene, 1878, p. 336.

evaporation, must perceptibly affect the amount of water contained in the soil, and moisten the air and lower its temperature.

It has been noticed that the temperature and humidity of the atmosphere are more uniform in woods than in the open fields; it has also been observed that while the evaporation from the surface of the ground in wooded districts is less than from the surface of the open ground, this deficiency is compensated by increased evaporation of moisture from leaves, which is mainly derived from the soil by the roots of the trees. Woodlands are said to cause increase of rainfall. This, to some extent, may be true, at least within their own limits. They certainly do increase the frequency of showers, and, in this way, equalize the distribution of the amount of precipitation.

Trees affect the drainage of the soil by their mechanical action. To some extent they impede the flow of water over the surface. There is very considerable resistance to the transmission of water beneath the surface in the superficial strata. This resistance is caused by the roots, which conduct the water along their surface, through the deeper and less permeable layers, and oppose a closely-wattled barrier to its movement along the slope of the superficial and more permeable strata which have absorbed it.[1] By retarding the passage of water through the soil, the roots of trees tend to prevent the sudden rise of streams and destructive floods. The roots of trees enter fissures of rock, and, by their growth, tend to enlarge them, and greatly increase the drainage capacity of the soil. They are known to penetrate through layers of the subsoil which resist the passage of water, and by perforating these strata like a sieve, furnish an outlet to the moisture which would otherwise accumulate in the superficial soil.[2] The most disastrous results have followed the destruction of forests, by obliterating these channels of drainage. "Thus in La Brenne, a tract of 200,000 acres resting on an impermeable subsoil of argillaceous earth, which ten centuries ago was covered with forests interspersed with fertile and salubrious meadows and pastures, has been converted, by the destruction of the woods, into a vast expanse of pestilential pools and marshes. In Sologne the same cause has withdrawn from cultivation and human inhabitation not less than 1,100,000 acres of ground once well-wooded, well-drained, and productive."[3]

Collections of trees oppose a mechanical impediment to the movement of winds. In a dense forest the air may be calm when it is fierce without. A belt of woodland acts as a screen against the diffusion of malarial exhalations. The rows of trees planted in the Tuscan Maremma on a large

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[1] Marsh: The Earth as Modified by Human Action, 1874, p. 235.

[2] "The roots of vegetables perform the office of draining in a manner analogous to that artificially practised in parts of Holland and the British Islands. This method consists in driving deeply down into the soil several hundred stakes to the acre; the water filters down along the stakes, and in some cases as favorable results have been obtained by this means as by horizontal drains."—d'Héricourt, Annales Forestiers, 1857, p. 312.

[3] Marsh: Op. cit., p. 205.

scale, by the advice of a commission appointed to devise measures for the sanitary improvement of this district, were planted with the distinct object of intercepting the pernicious exhalations from malarious localities. Whether the agency is simply mechanical, or whether trees possess the power of neutralizing the poison by the action of ozone,[1] or some other chemical agency,[2] has not yet been determined. Vegetation may do harm by excluding the air and preventing proper ventilation. It may be injurious, especially where the drainage is defective, and where decaying organic matter is present.

"So far as we are able to sum up the results, it would appear," says Marsh,[3] "that, in countries in the temperate zone still chiefly covered with wood, the summers would be cooler, moister, shorter, the winters milder, drier, longer, than in the same regions after the removal of the forest, and that the condensation and precipitation of atmospheric moisture would be, if not greater in total quantity, more frequent and less violent in discharge."

Covering the surface with grass, plants, and the more diminutive forms of vegetation, has a healthful influence. The beneficial effects of the cultivation of the soil are well understood. The existence of brushwood is indicative of neglect of the soil, and is frequently associated with an unhealthy locality. The judicious planting and removal of trees about a habitation may add materially to the healthfulness of the place. In hot countries trees protect against the ardent rays of the sun, and produce a cooling effect upon the air. In cool countries they ward off chilling blasts; in both they may be used as a barrier to malarious currents of air. The *Eucalyptus* tree is just now much in favor on account of its rapid growth, its great power of absorbing moisture from the soil and exhaling it into the atmosphere, and also on account of a supposed special counteracting influence upon the malarial poison itself. Unfortunately, it thrives only in a warm climate, and its use will necessarily be restricted to a comparatively limited area.

Soils considered in relation to heat, light, malaria, etc.—Soils differ in their power of absorbing the heat of the sun. The differences depend mainly upon the color, composition, and texture of the soil. The inclination and form of its surface, the form and character of the substances upon it, and its humidity, are all modifying influences. A difference of 32° Fahr. has been observed between the temperatures of a naked rock and one covered with vegetation, the observations being taken at the same time and in the same locality (Parkes).

Absorption of heat takes place upon the surface, or at least within a very superficial stratum. The heat is disseminated slowly downward by conduction, and is also imparted to the atmosphere by surface communication and by radiation. As different soils have different powers of

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[1] Ebermeyer: Die Physikalischen Einwirkungen des Waldes, 1873, pp. 237 et seq.

[2] Selmi: Il Miasma Palustre, 1870, pp. 109 et seq.

[3] Op. citat., p. 199.

absorption, they have also different powers of radiation, and the power to absorb heat is proportional to the power of radiation.

The intensity of radiation increases rapidly with the temperature of the radiant surface. In hot climates it is not unusual to find a temperature of 120° to 140° Fahr., and even more, on the surface of dry and light soils.[1]

Herschel[2] observed it at 159° Fahr. at the Cape of Good Hope, and Parkes cites Buist as authority for the statement that in India the thermometer, placed on the ground and exposed to the sun, will mark 160° Fahr., while two feet from the ground it will only mark 120°.

The following table furnishes the results of experiments made by Shübler for determining the degrees in which various soils possess the property of absorbing and retaining heat:

Soils as regards power of retaining heat; 100 *being assumed as the standard.*

Sand, with some lime	100.0
Pure sand	95.6
Light clay	76.9
Gypsum	73.2
Heavy clay	71.1
Clayey earth	68.4
Pure clay	66.7
Fine chalk	61.8
Humus	49.0

It is evident from the above experiments that sandy soils are the hottest and clayey soils and humus the coldest.

Becquerel[3] says: "Other things being equal, siliceous and calcareous sands, compared in equal volumes with different argillaceous earths, with calcareous powder or dust, with *humus*, with arable, and with garden earth, are soils which least conduct heat. It is for this reason that sandy ground, in summer, maintains a high temperature, even during the night. . . . . After the sands follow, successively, argillaceous, arable, and garden ground; then humus, which occupies the lowest rank.

"The retentive power of humus is but half as great as that of calcareous sand. We will add that the power of retaining heat is proportional to the density. It has also a relation to the magnitude of the particles. It is for this reason that ground covered with siliceous pebbles cools more slowly than siliceous sand."

With respect to the property of absorbing heat, in temperate climates sandy soils are generally considered to be healthier than argillaceous soils, the latter being cold and damp, and, therefore, favorable to

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[1] Müller: Principles of Physics and Meteorology, 1848, p. 575.

[2] Meteorology, 1861, p. 41.

[3] Des Climats, etc., p. 137.

the production of catarrhal and rheumatic affections. It is otherwise in hot climates, where a sandy soil, by having a high degree of heat by night as well as in the daytime, tends to maintain a high temperature of the atmosphere. Clayey soils part with their heat more rapidly, and have the effect of cooling the atmosphere.

A stony, sandy, barren soil, with scanty verdure, or deprived of it altogether, absorbs heat more rapidly, and is hotter than one that is covered with vegetation. When the ground is shielded with vegetation, the rays of the sun do not fall upon it directly, but mostly through the medium of heated air; it therefore remains cooler. Moreover, the vegetation is constantly evaporating moisture, and cools considerably by nocturnal radiation, so that the temperature of the grass often falls 10° to 15° Fahr. below that of the air. For this reason the interior of woods and forests is cool, their foliage acting in the same cooling manner as the covering of grass.[1]

The earth receives the solar heat upon its superficial surface, and slowly imparts it to the ground beneath by the power of conduction. Toward night this ceases, and the "wave of heat" recedes toward the surface. The diurnal variation of temperature becomes less as the depth increases, and the point at which it disappears varies with the capacity of the soil for conducting heat, and with the season. "In ordinary soils the difference between the diurnal and nocturnal extremes becomes imperceptible at four feet below the surface. (Quetelet: Mem. Acad. Brux., 1836.) In like manner, the general increase of heat due to the summer season, and of cold during winter, are propagated in similar but larger and feebler annual waves, which in their turn neutralize each other at more considerable depths, and become imperceptible at forty or fifty feet. Professor Forbes has shown, in an elaborate memoir on the subject (Trans. R. S. Edin., XVI.), that at depths varying from 57 to 99 feet, according to the nature of the soil, the annual variation does not exceed 0.01° C.[2]"

There can be no doubt that one of the advantages derived from deep drainage of the soil results from the improvement of its temperature. Josiah Parkes showed by his experiments an increase of 10° Fahr. in the temperature of drained land over undrained bog-land, at 31 inches below the surface; and Shübler cites an instance where, on land that had been well aërated (drained), the mean annual temperature was raised 6° Fahr. at a depth of four feet. Drainage contributes to the dryness of the soil, and improves its temperature, not only by diminishing evaporation and increasing the hygroscopic powers of the soil, but by increasing the power to absorb the rays of heat.

The influence of the temperature of the soil upon the causation of disease is undoubted. Heat is one of the factors concerned in the production of malaria, and it also probably aids in the elaboration of the poison of cholera, typhoid fever, and other diseases.

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[1] Müller: Principles of Physics and Meteorology, 1848, p. 575.

[2] Herschel: Meteorology, 1861, p. 42.

The reflection of *light* by the surface of different soils varies with the color. Light-colored soils reflect light with great intensity; and they are also hot, as the reflecting power of a surface for heat and for light is the same. Light reflected from a white, glaring surface, and continued for any length of time, tends to impair vision. The glare from the white sands of the seashore have this effect. The night-blindness of the tropics, due to a blunted sensibility of the retina, is caused by constant exposure to the strong glare of the sun. The soldiers in the Crimean war, and in the late American war, frequently suffered from this defect of vision. The reflection of light from a field of snow sometimes produces temporary blindness. The use of the means to absorb the light to the extent of rendering it less hurtful need not be suggested.

Marshy districts are the haunts of malaria in almost all countries. There are many exceptions, which it is difficult to explain. For example, the swampy lands in many of the islands of the Pacific and on the coast of Australia, and many of the marshes along the Atlantic coast of the United States, though apparently possessing all the conditions for the development of malaria, are comparatively free from the poison. Jourdanet[1] mentions, as a notable case, the lake of Tescudo, situated close by the city of Mexico, and covering, at ordinary times, an area of twenty-five square miles, whose clayey bottom is, at certain seasons, frequently exposed to a considerable extent as the result of extremely active evaporation under a high degree of temperature, without giving rise to malarial fevers. Marshes that are subject to a regular tidal overflow by the sea are, as a rule, free from malaria, though this point has been contested. Many of the watering-places situated along the Atlantic coast of this country close to salt marshes are comparatively free from malarial diseases. Whenever there is an occasional overflow, or when there is a mixing of salt and fresh water in coast-marshes, the conditions are most favorable to the development of highly noxious effluvia. It is believed that the salt-water has the effect of killing many fresh-water plants and animals, and that the fresh water in a like manner is destructive of marine organisms, thus producing organic decomposition and the exhalation of poisonous miasms.[2] The sanitary condition of the territory known as the Tuscan Maremma, a marshy district lying upon the western coast of Italy, which has been proverbially unhealthy for centuries, has been vastly improved by filling up the marshes and lagoons with the sedimentary deposits from the surface-waters, and by the separation of the waters of the sea and of the land. In speaking of the effect of these operations in the Val di Chiana, Marsh says that "the fevers, which not only decimated the population of the low grounds, but infested the adjacent hills, have ceased their ravages, and are now not more frequent than in other parts of Tuscany." Marsh lands are particularly unhealthy when their *surface*, previously saturated with water, is exposed to the heating influence of the sun, and

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[1] L'Union médicale, 1862, No. 129, p. 212.

[2] Salvagnoli: Rapporto sul Bonificamento della Maremme Toscano, 1860.

becomes, to a certain extent, desiccated. By the sinking of the groundwater, not only the surface, but the superficial soil is directly subjected to the action of heat and air, conditions most essential to the evolution of malaria. Ferguson says that paucity of water, where it has previously and recently abounded, is an indispensable condition to the production of marsh poison, and "to this there is no exception in climates of high temperature."

A mode of irrigation, practised at one time in certain departments of France, particularly in Brenne, Sologne, and Dombes, which consists in submerging tracts of land for a year or more, and subsequently draining and cultivating them, rendered the country almost uninhabitable.[1] The irrigation of rice fields, which consists in alternately flooding and draining the grounds, is productive of malarious fevers. Rice cultivation has proved so much more pestilential in Southern than in Northern Italy that it has long been discouraged by the government.[2]

Organic matter is present in considerable quantity in the air of marshes, and so far as investigations have been pursued, this matter is found to possess the same general character. Carbonic acid is in excess. Sulphuretted, carburetted, and phosphuretted hydrogen gases are often evolved from marsh land. Free hydrogen and ammonia may also be present. Living organisms, vegetable débris, and spores[3] of plants have been found in considerable quantities.

Malarious marshes are flat, poorly drained, and hold a large amount of water without flooding; they contain large quantities of organic matter—10 to 45 per cent. (Parkes)—and mineral compounds, such as silicates of alumina, sulphates of lime, magnesia, etc. Vegetable organic matter is in excess. Vegetation is usually abundant, but this latter feature is no longer considered of very great importance in relation to the propagation of malaria.

Alluvial soils, generally speaking, are productive of malaria. For this reason bottom lands, low lands bordering on rivers which are occasionally flooded, and the deltas of large streams, are very unhealthy. Soils occasionally receiving the washings of rivers composed of loose sand, gravel, and mud, with a certain admixture of organic matter, are to be regarded with suspicion. The draining of ponds, lakes, and watercourses has frequently been followed by malarial fevers. The deltas of rivers formed by the deposit of detritus carried down by the current are proverbially unhealthy. Those of the Nile and the Po, and the islands of the Walcheren, are prominent examples. Recently formed alluvial soil may give rise to the poison, as pointed out by Wenzel.[4] During the construction of the harbor of Wilhelmshaven, on the bay of Jade, it appears, from his report,

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[1] Dunglison: Elements of Hygiene, p. 115.

[2] Marsh, op. cit., p. 468.

[3] Salisbury: Amer. Jour. Med. Sciences, 1866, p. 51; and Balestra: Comptes rendus, 1870.

[4] Prager Vierteljahrschr., 1870, IV., p. 1.

that malarial diseases became epidemic, and then gradually subsided with the more advanced condition of the banks and the betterment of the surrounding territory.

Digging up the soil, excavating for canals, building dykes, the clearing and preparation of lands for their first cultivation, by exposing earth containing matters which have long remained in a quiescent state to the energetic action of the sun, may subject people living in the neighborhood to an attack of malarial disease.

Sandy soils, though usually regarded as healthy, are sometimes malarious. Such soils, when superficial, are sensibly affected by the character of the substratum. If covering an argillaceous or clayey bed, impervious to water, or if so situated as to maintain a high level of the ground-water, they are kept constantly humid by the evaporation from below; and though the surface may be dry, and even parched, the conditions beneath it, especially when organic matter is present in the sand, are those which materially aid in the development of the malarial poison. Dr. Ferguson records an epidemic of intermittent fever that prevailed in August, 1794, among the British troops encamped at Rosendaal and Oosterhout, in South Holland. The soil in both places was a level plane of sand, with a perfectly dry surface, where scarcely any vegetation existed ; but beneath the surface, and close to it, the soil was infiltrated with water. The summer had been very hot and dry. Sandy plains, that receive from neighboring hills the surface-waters mixed with animal and vegetable impurities, or that lie upon an impermeable stratum which collects the organic matters carried down into the soil by the percolation of rain-water, such as the Landes of Gascony, have been known to cause malarial fevers at certain periods of the year.

Shallow rock-basins, having no outlet, hold the surface-waters and whatever ingredients they may contain. Such a formation may be the governing cause of the prevalence of fevers.

Some rocky soils have been classed among the number of those having a malarious character. It is hardly to be supposed that the disintegrated rock itself is the active agent, but simply that in a rocky district the essential elements may all be present. The fissures and chasms in the rocks containing moist and decaying detritus, and the half-dried ravines and beds of streams may furnish the very conditions essential to the emission of miasmata.

Many malarious soils contain ferruginous matter (*i. e.*, oxides of iron), and it has been suggested that this ingredient may in some way be connected with the production of the poison; but the evidence on this point is not conclusive.

EXAMINATION OF THE SOIL.

An examination of the soil in its sanitary bearings should embrace, in its scope, not only the superficial layers, but also the subsoil to a depth of ten or twelve feet or more. The organic and inorganic constituents of the soil should be determined by a simple method of analysis, such as the one to be indicated. The physical properties, especially in their relation to heat, moisture, and air, are not less important. The state of the ground-water, particularly the variations in its level, should be carefully noted. Analyses of the ground-air and ground-water are not usually recommended in ordinary examinations, but they are essential to the completeness of the investigation. It is necessary to bear in mind that the character and arrangement of the underlying rocky strata exert a marked influence upon the superimposed soil, especially in regard to the movement of water, and therefore a familiarity with the general geological conditions of the locality is of importance. For example: a comparatively impervious rocky basin, having no outlet, will hold water as in a dish, and will keep the soil above it constantly more or less moist, no matter what may be its properties.

Many of the more prominent characteristics of the soil, such as color, temperature, porosity, density, composition—that is, whether sandy, gravelly, clayey, etc., can be readily determined by an ordinary examination. The conformation of the surface and the meteorological phenomena of the locality should also be regarded. The subsoil may in like manner be examined by digging holes ten or twelve feet deep, care being taken to observe any variation in the appearance of the soil as removed. Water should be poured on different samples, and the effect noticed. The distance of the level of the ground-water from the surface should be carefully ascertained. After rain, holes should be dug, in order to determine the depth to which the water has penetrated the ground.

The temperature of the soil should be taken at its surface and at different depths beneath it. The depth selected by Lewis and Cunningham, for an extended series of observations made at Calcutta, was six feet from the surface.[1] Thermometers furnished with long tubes are buried in the ground, and their indications recorded daily. Observations should be taken at least twice a day, *i. e.*, early in the morning and at the hottest part of the day.

Soil-temperature is known to have an important influence upon soil-ventilation and soil carbonic acid, and, as thus associated, has been studied in connection with the level of soil-water, with reference to its influence upon the prevalence of certain diseases, as cholera, for example. The investigations are as yet too limited to be of much value, but they promise to yield important results.

The mineral constituents, which are very numerous, rarely occur alone, two or more of these elements being associated together in a homogeneous mass, and thus constitute rocks, of which the bulk of the earth's crust is composed. The soil is formed of these rocks, in a more or less disintegrated state, with some admixture of organic matter. The principal ingredients to be searched for are silica, alumina, lime, iron, magnesia, potash, soda, chlorine, carbonic acid, and phosphoric acid. The un-

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[1] Cholera in Relation to Certain Physical Phenomena, Calcutta, 1878.

decomposed, solid parts of the soil may be examined with reference to their mineralogical character. The ordinary rocks, such as granite, trap-rocks, gneiss, mica slate, clay slate, sandstone, and limestone, can be distinguished without much difficulty. Limestones may be designated from rocks having a similar appearance by their effervescence upon the application of a few drops of hydrochloric acid.

A simple analysis of the soil may be made in the following manner: Take a portion of the soil, free from any large stones, dry it, and weigh it; then having carefully removed and weighed the solid mineral ingredients, separate the finer particles by passing them through a sieve. That portion of the sample remaining in the sieve may then be thoroughly mixed with water, and the suspended particles poured off. The residue is again stirred up with fresh water, and this poured off after the dense particles, including sand, have settled. The difference between the combined weight of the solid mineral fragments and the dried coarser particles left after treating with water, and the weight of the original mass, will be the amount of the fine earthy substance, probably, for the most part, an impure silicate of aluminum.[1]

If desired, a more elaborate examination of the physical and chemical properties of the soil may be made in the laboratory.

For this purpose take a fair sample of the soil (about ten or twelve pounds) free from any large stones, dry it by exposure, in summer, to the ordinary temperature in the shade, or, in winter, in a warm room, or in a moderately warm drying-chamber heated to a temperature of 85° to 100° F. Separate the larger stones and pebbles from the finer parts, by hand, or by a coarse sieve, and determine their mineralogical character. Pulverize the soil in a mortar with a wooden pestle, or by rubbing it between the hands, and then pass it through a sieve. The following points may then be determined:[2]

1. *Amount of hygroscopic water.*—To estimate the amount of hygroscopic moisture, heat ten grammes of the soil, previously air-dried, at a temperature of 212° F. till it ceases to lose weight, then reweigh it; the difference is the hygroscopic water.

2. *Amount of organic matter, or other volatile matters besides water.*—Take a weighed quantity of the same soil, and incinerate it in a platinum tray or crucible, heated over the gas-lamp; the carbonic acid belonging to the inorganic part of the soil, as, for example, in the form of carbonate of lime, must be restored by moistening the ignited residue with ammonium carbonate; dry, gently ignite, and weigh. From the loss of weight, subtract the amount of water in the quantity taken, calculated from the results of an estimation of hygroscopic water in another portion of the same soil, and the remainder will be the organic matter, or other volatile matters besides water.

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[1] Stöckhardt: Agricult. Chemistry, 1855, p. 283.

[2] See Agricult. Chem. Analysis; Wolff, Fresenius, Krocker, and others, edited by Caldwell, 1869.

3. *Power of retaining hygroscopic water.*—This is approximately determined by the process given above. The influence of temperature upon this property of the soil may be determined by spreading a thin layer of the soil, carefully weighed, on a shallow dish, and noting the changes in weight from time to time when it is exposed to sunlight while protected from currents of air, or to a temperature of 70°, 85°, and 100° F. The amount of moisture absorbed from a saturated atmosphere may be determined by placing the soil on the same shallow dish, as above described, together with a shallow vessel of water, under a bell-jar, and weighing several times in the twenty-four or forty-eight hours. The increase in weight is the water absorbed. The temperature should be observed.

4. *The power of the soil to retain liquid water.*—To determine the power of the soil to hold water, take a zinc box, 17 ctm. deep, and 3 ctm. square, whose bottom is perforated with numerous small holes; cover the bottom with a piece of moistened fine linen, and weigh the box; then fill the box with the air-dried soil, and weigh it again. Immerse in water to the depth of 3 or 4 mm., noting how long a time is required for the water to reach the surface, and allow the box to remain in the water until there is no further change in weight. The amount of water absorbed by 100 parts of the soil may then be calculated. It may be observed that the determinations made in the laboratory do not furnish a true expression of the actual amount of water absorbed by soils in their natural position, but simply indicate the relative absorbing capacities of different soils.

5. *The porosity of the soil.*—The porosity of the soil, or the ratio between the volume of the solid particles and that of the spaces filled with air or water, is estimated by dividing the apparent specific gravity of the soil, dried at 212° F., by the real specific gravity. The calculation for 100 volumes of soil will be as follows:

$$\frac{\text{Apparent specific gravity} \times 100}{\text{Real specific gravity}} = \begin{array}{c}\text{the volume of solid particles in 100}\\ \text{parts of the soil.}\end{array}$$

Then 100—vols. of solid particles = the volume of the pores.[1]

6. *Substances soluble in water.*—It is important to determine the organic and inorganic matters in the soil, soluble in water, with reference to the possible contamination of drinking-water from this source. Place in a flask about 500 grms. of the air-dried soil to be examined, and pour over it about 2,000 c.c. of pure water, carbonated. Leave the water in contact with the soil for several days in the flask, which should be well stoppered, occasionally agitating the mixture briskly. Pour off 1,000 c.c. of the clear liquid, representing 250 grms. of the soil, filter it, and evaporate the filtrate to dryness, at a temperature below the boiling point; dry the residue at about 260° F., weigh and ignite, and, after treatment with ammonium carbonate and gentle ignition, weigh again. The difference between the two weights will be the amount of organic matter taken up by the water. A similar solution may be prepared in larger quantities,

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[1] The specific gravity may be estimated by the method in use for determining the specific weight of a powder, namely, that of the specific gravity bottle.

and tested for other substances according to the plan laid down in the chapter on drinking-water.

7. *Substances soluble in hydrochloric acid.*—Pure hydrochloric acid is used as a solvent of those substances not taken up by water. Parkes[1] furnishes the following tests:

"(*a*). To 40 grms. of the soil add one ounce of pure hydrochloric acid, and heat; note effervescence. Add about 100 c.c. of water. Digest for twelve hours. Dry and weigh the undissolved portion.

"(*b*). To the acid solution add ammonia. Alumina and oxide of iron are thrown down. Dry and weigh precipitate.

"(*c*). To the solution filtered from (*b*) add ammonium oxalate. Dry; wash and burn the calcium oxalate. Weigh as carbonate.

"(*d*). To the solution filtered from (*c*) add sodium phosphate. Collect; dry and weigh (100 parts of the precipitate = 79 parts of magnesium carbonate), or determine as pyrophosphate.

"The portion insoluble in hydrochloric acid consists of quartz, clay, silicates of alumina, iron, lime, and magnesia. If it is wished to examine it further, it should be fused with three times its weight of carbonate of sodium, then heated with dilute hydrochloric acid. The residue is silica. The solution may contain iron, lime, magnesia, and alumina. Test as above.

"Iron can be determined by the bichromate of potassium, or by the permanganate. As the latter solution is used for other purposes, it is convenient to employ it in this case.

"Dissolve 10 grms. of the soil in pure hydrochloric acid free from iron, by aid of heat. Add a little pure zinc, and heat to convert ferric into ferrous salts. Pour off the solution from the zinc that is still undissolved, and determine iron by potassium permanganate, *i. e.*, heat to 140° F., and then drop in the solution of permanganate till a permanent, but slightly pink color is given.

"The solution of potassium permanganate is made by dissolving 0.395 grms. of the crystallized salt in one litre of water."

SELECTION OF SITE.

The question of the selection of the sites of cities and towns is seldom decided by hygienic laws. Facilities for commerce, trade, and for the development of industries have been more powerful considerations. Many a town owes its origin to the cupidity of the speculator. Consequently it often happens that localities are selected which are totally unfitted for human habitations. Towns are erected without sanitary regulation, and not until the evils, which prudence and foresight could have foretold and prevented, have become alarming and attract public attention, are measures adopted to counteract vices of location, and to modify the effects of errors of plan and construction.

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[1] Practical Hygiene, 1878, p. 346.

The selection of the site of isolated homes is less influenced by the circumstances which govern the location of towns.

The principal points to be observed in selecting a site may be alluded to under the following heads:

1. *Meteorological phenomena.* — A knowledge of the state of the weather at all seasons of the year, and of its influence upon the conditions of the soil, should be obtained before making a choice of a locality. The prevailing winds, the frequency and quantity of rainfall, the temperature, and the prevalence of mists or fogs, all modify, to a greater or less degree, the character of the soil. Mists or fogs are always unhealthy. Therefore a locality bordering on low or marshy lands, or on bodies of water over which fogs are generated, should be avoided. Lands not evidently wet are sometimes the cause of fogs. Sudden vicissitudes of temperature, often caused by conditions of the ground, as, for example, the evaporation of moisture, are injurious to health.

2. *Conformation and elevation.*—These are both important considerations. Inclosed valleys are usually unhealthy, on account of dampness and stagnation of air. Flat surfaces at the foot of hills, even though the soil be of a favorable composition, may be unhealthy by being impregnated with organic matters carried down by rains from the neighboring slopes, or on account of dampness caused by the pressure of water from higher levels. A break in the surface at the foot of hills, such as a deep ravine, will act favorably in such cases by intercepting the surface and soil-waters from the higher districts.

The exposure to winds should be noted. Conformation of the surface has an important influence in determining the force and direction of winds. A situation near the top of a slope is usually more desirable than one upon the summit or at its base. A valley with contracted outlet may be unhealthy, on account of the impediment to the discharge of water and the overflow from rains. Places screened from the proper amount of sunlight, and deprived of the free circulation of air, are apt to be damp and chilly, and therefore undesirable.

Elevated lands with a good slope are generally considered salubrious, since they afford better facilities for drainage, freer evaporation, comparative exemption from malaria, and purer and drier air. Malaria sometimes occurs in elevated and mountainous regions. The citizens of the towns on the Southern Atlantic and Gulf coasts are in the habit of retreating to the higher lands, during the sickly summer season, to escape diseases prevalent, during this period, in the low lands along the coast. Elevation is said "to possess qualities preventive of certain diseases and curative of others." High elevations are frequently selected as sites for health resorts. (See Climate.)

The geological features should be observed, particularly as influencing the movement of water through and over the ground, and the character of the water obtained from wells. An examination of the character and inclination of the geological strata will often decide a question of drainage. A gentle slope, or an undulating surface, has great advantages, not only for natural drainage, but in the construction of works for the removal of subsoil-water and sewage. On the other hand, a dead level impedes drainage, and is especially objectionable if the ground be of an impermeable character.

3. *Composition of the soil.*—The constitution of the ground under and surrounding a dwelling is one of the weightiest considerations. No soil, however favorable its external appearances, can be safely selected as the site for habitations without a careful examination of the substances of which it is composed, organic as well as mineral. And such an examination should include the different strata to a depth of ten or twelve feet. The presence of organic matter is a suspicious circumstance, and a soil containing it in large quantity should be avoided. Vegetable débris, produced by the decay of plants, will be found in the superficial layer of almost all soils.

A soil composed of clean gravel, free from clay and effete organic matter, and having a porous substratum, has the advantages of free ventilation and drainage, and a low level of the ground-water—all essential qualities for a dry and salubrious site. The permeable sandstones and chalk formations make good sites. Rocky and stony situations are usually healthy. Sandy soils furnish both healthy and unhealthy sites. They are regarded as salubrious, provided they are clean and pure, and that they are not water-bound by an impermeable foundation. Clay, and alluvial soils generally, are regarded as unhealthy.

4. *Physical conditions, etc.*—The power of the soil to absorb moisture from the air, to take up and retain liquid water, to become dry by evaporation, and to absorb and retain heat, should be a subject of inquiry. The amount and quality of the ground-air, especially its percentage of carbonic acid, as a measure of its impurity, but more particularly the state of the ground-water, are to be carefully determined. The height of the ground-water at different seasons of the year, and the character of the fluctuations in the water-level, should be observed. A persistently low water-level is healthy; but a high water-level, especially if the changes are sudden and violent, is very unhealthy. Dryness of the soil is one of the most essential points in selecting a site. Vegetation modifies the conditions of the soil, and exerts an important influence upon the salubrity of a locality. The water-supply, whether derived from wells or from rivers, has a bearing upon the subject. A healthy site is dependent, in some measure, upon the condition of the neighboring lands and bodies of water. Dampness may be communicated to the soil from meadows, marshes, ponds, and rivers, though located at a distance. Places subject to inundations may have a sickly season.

Says Dr. Bowditch,[1] in speaking of the prevalence of consumption in New England, in connection with influences derived from the soil: "In choosing a site for a dwelling-house, the great desideratum is to obtain, not a perfectly *arid* place, for no such spot could be inhabited by

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[1] Op. citat., p. 123.

man, but it should be in a portion of the township which is neither so high as to be exposed to violent gusts of weather, nor so low that moisture will collect around it. Let it be on the side of a hill, or plain, open to the south, and, if possible, defended from the north and east, on a dry, porous soil, through which water freely percolates, and which, even after a rain, retains little moisture."

Dr. James Clark[1] is equally decided in the opinion that dryness is the most essential physical quality of the soil and atmosphere to be taken into consideration when selecting a situation for a dwelling-house. He says: "It may be stated as a general rule that houses in confined, shaded situations, with damp courts or gardens, or standing water close to them, are unhealthy in every climate and season; but especially in a country subject to intermittent fevers, and during summer and autumn. In our own country nothing is more common than to see houses built in very unhealthy situations, a few hundred yards distant only from a good one. Again, houses in places otherwise unexceptionable, are often so closely overhung with trees as to be rendered far less healthy residences than they otherwise would be. Thick and lofty trees close to a house tend to maintain the air in a state of humidity, by preventing its free circulation and by obstructing free admission of the sun's rays. Trees growing against the walls of houses, and shrubs in confined places near dwellings, are injurious also, as favoring humidity; at a proper distance, on the other hand, trees are favorable to health. On this principle it may be understood how the inhabitants of one house suffer from rheumatism, headache, dyspepsia, nervous affections, and other consequences of living in a confined, humid atmosphere, while their nearest neighbors, whose houses are more openly situated, enjoy good health; and even how one side of a large building, fully exposed to the sun and to a free circulation of air, may be healthy, while the other side, overlooking damp, shaded courts or gardens, is unhealthy. The exemption of the central parts of a large town from these fevers is partly explained by the dryness of the atmosphere which prevails there and the comparative equality of temperature. Humid, confined situations, subject to great alternation of temperature between day and night, are the most dangerous. Of all the physical qualities of the air, humidity is the most injurious to human life; and, therefore, in selecting situations for building, particular regard should be had to the circumstances which are calculated to obviate humidity, either in the soil or atmosphere, in every climate. Dryness, with a free circulation of air, and a full exposure to the sun, are the material things to be attended to in choosing a residence."

The healthiness of a site may be greatly improved:

1. By thorough surface and subsoil drainage.
2. By free access of air and sunlight.
3. By the use of the well-known means to insure perfect dryness of the walls and basement, and the exclusion of the ground-air.

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[1] The Influence of Climate, etc., 1830, p. 155.

4. By the regulation of vegetation; that is, by removing or planting trees, etc., according to circumstances of soil, climate, etc., etc.

5. By preventing the pollution of the soil, by the use of the best means for carrying off the surface-water, house-water, and all house-offal as rapidly as possible.

SECTION II.

POLLUTION OF THE SOIL.

Pure air, pure water, and pure nutritious food are essential to health. Hardly less important is it that the ground should be secured against every source of contamination. Air and water are more or less directly influenced by the soil, and if the latter becomes defiled, the former are exposed to the danger of pollution from this source. A soil favored by nature with all the advantages required for a healthy site may become so impregnated with impurities as to be in the highest degree prejudicial to health. It is the province of the sanitarian to guard against these dangers, by pointing out the means of their prevention, and by suggesting the remedies when the evils have already occurred.

The ways in which a soil may become polluted are as follows ;

1. By excreta.
2. By interments.
3. By coal-gas.
4. By surface defilement.

I. POLLUTION OF THE SOIL BY EXCRETA.

Of all the forms of soil contamination, that by excremental matter is the most frequent, the most dangerous, and, in practice, the most difficult to prevent. This waste matter, discarded by the human economy as no longer useful for its purposes, and even hurtful to its vital actions, is offensive and repulsive to the senses, nature intimating thereby that its removal and transformation should be prompt and effectual. And experience has demonstrated clearly, by most ample and positive proof, the evil consequences of the neglect of this primitive sanative principle. Nevertheless, this deleterious refuse-matter is frequently suffered to remain near dwellings and wells, and to collect in cesspools and privies, whence it passes by leakage or soakage into the surrounding soil, polluting the very foundations of habitations, and the air which is drawn up into their apartments through the basement floors. It trickles into the neighboring wells that furnish the water-supply, and is exhaled from the soil in the form of gaseous vapors. The same effects are produced by faulty drain-pipes and faulty sewers.

Dr. Simon[1] has described this common and deplorable neglect in the following terse sentences: "There are houses, there are groups of houses, there are whole villages, there are considerable sections of towns, there are even entire and not small towns, where general slovenliness in everything which relates to the removal of refuse-matter, slovenliness which in very many cases amounts to utter bestiality of neglect, is the local habit: where, within or just outside each house, or in spaces common to many houses, lies for an indefinite time, undergoing fetid decomposition, more or less of the putrefiable refuse which house-life, and some sorts of trade-life, produce: excrement of man and brute, and garbage of all sorts, and ponded slop-waters; sometimes lying bare on the common surface; sometimes unintentionally stored out of sight and re-collection in drains or sewers which cannot carry them away; sometimes held in receptacles specially provided to favor accumulation, as privy-pits and other cesspools for excrement and slop-water, and so-called dust-bins receiving kitchen-refuse and other filth. And with this state of things, be it on large or on small scale, two chief sorts of danger to life arise: one, that volatile effluvia from the refuse pollute the surrounding air and everything which it contains; the other, that the liquid parts of the refuse pass by soakage or leakage into the surrounding soil, to mingle there of course in whatever water the soil yields, and in certain cases thus to occasion the deadliest pollution of wells and springs. To a really immense extent, to an extent indeed which persons unpractised in sanitary inspection could scarcely find themselves able to imagine, dangers of these two sorts are prevailing throughout the length and breadth of this country, not only in their slighter degrees, but in degrees which are gross, and scandalous, and very often, I repeat, truly bestial. And I state all this in unequivocal language, because I feel that, if the new sanitary organization of the country is to fulfil its purpose, the administrators, local and central, must begin by fully recognizing the real state of the case, and with consciousness that in many instances they will have to introduce for the first time, as into savage life, the rudiments of sanitary civilization."

One of the channels through which a contaminated soil exerts an injurious influence upon health, is the water of wells used for drinking purposes. Cesspools, common privies, or faulty drain-pipes, in close proximity to wells, are, in this way, a fruitful source of mischief. Precautions may be taken to lessen the risk of soakage into wells, but it is unsafe to depend upon them, and in crowded localities, where the soil is liable to become saturated, privy-wells and cesspools, and other receptacles for filth of the accumulative sort, had better be abandoned altogether.

The extent to which the soil is polluted by excreta and other refuse-matter, in the rural and small urban districts in England, and the danger of the contamination of drinking-water from this source, may be learned from the report[2] of the Rivers' Pollution Commissioners, in which they say that, estimating the town population of Great Britain at about fifteen

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[1] Filth-Diseases and their Prevention, Boston, 1876, p. 33.

[2] Sixth Report.

millions, "the remaining twelve millions of country population derive their water almost exclusively from shallow wells, and these are, so far as our experience extends, almost always horribly polluted by sewage and by animal matters of the most disgusting origin. The common practice in villages, and even in many small towns, is to dispose of the sewage and to provide for the water-supply of each cottage, or pair of cottages, upon the premises. In the little yard or garden attached to each tenement, or pair of tenements, two holes are dug in the porous soil. Into one of these, usually the shallower of the two, all the filthy liquids of the house are discharged; from the other, which is sunk below the water-line of the porous stratum, the water for drinking and other domestic uses is pumped. These two holes are not unfrequently within twelve feet of each other, and sometimes even closer. The contents of the filth-hole or cesspool gradually soak away through the surrounding soil, and mingle with the water below. As the contents of the water-hole or well are pumped out, they are immediately replenished from the surrounding disgusting mixture, and it is not therefore very surprising to be assured that such a well does not become dry even in summer. Unfortunately, excrementitious liquids, especially after they have soaked through a few feet of porous soil, do not impair the palatability of the water; and this polluted liquid is consumed from year to year without a suspicion of its character, until the cesspool and well receive infected sewage, and then an outbreak of epidemic disease compels attention to the polluted water. Indeed, our acquaintance with a very large proportion of this class of potable waters has been made in consequence of the occurrence of severe outbreaks of typhoid fever among the persons using them."

This picture of sanitary neglect is hardly less applicable to this country, for although here it would be considered overdrawn, and properly so, there can be no doubt that it represents a condition that too commonly prevails in many rural and suburban districts.

A filth-sodden soil exerts a pernicious influence upon health through the medium of the effluvia which it emits. The soil, in crowded localities, is always more or less polluted by the oozings from cesspools and cesspits, and by leakage from badly constructed sewers and drain-pipes. And as the air, which is universally present in the ground, partakes of the character of the impurities, such a soil must of necessity produce a foul and pestiferous air. We have seen that the ground-air is in continual intercourse with our houses, and that this communication is especially active when the temperature inside is higher than that of the external air. Hence, the impurities in the soil, from whatever source, pollute the ground-air, and, through this medium, the air of our houses.

The pollution of the soil by excremental filth is of special importance in its relations to the causation of certain forms of disease of the so-called zymotic class, such as enteric fever, cholera, dysentery, etc., by reason of the liability of such nuisances to convey with them the "specific" germs of disease, which other equally offensive organic decomposition does not seem to possess, at least not in the same degree. Dr. Simon says: "The experience is, not only that privies and privy-drainage, with their respective stinkings and soakings, and the pollutions of air and water which are thus produced, have in innumerable instances been the apparent causes of outbreaks of enteric (typhoid) fever, but, further, that they have seemed capable of doing this mischief in a doubly distinctive way: first, as though by some aptitude which other nuisances of organic decomposition, though perhaps equally offensive, have not seemed equally, or nearly equally, to possess; and, secondly, as though this specific property, so often attaching to them in addition to their common septic unwholesomeness, were not, even in them, a fixed property. The explanation of this experience, the explanation of the frequent but not invariable tendency of privy nuisances to infect with enteric fever, has seemed to consist in the liability of such nuisances to carry with them, not invariably, but as frequent accidental adjuncts, the 'specific' contagium of any prevailing bowel infection; for, presumably, the privies of a population receive, with various other things, the diarrhœal discharges of the sick; and it has long been matter of fair pathological presumption that in any specific diarrhœa (such as eminently is enteric fever), every discharge from the bowels must teem with the contagium of the disease." After referring to the similar relation of other diseases to excremental infection, he remarks that "it would thus seem probable that air and water, having in them the taint of human excrement, must often carry with them, whithersoever they pass, the seeds of current morbid infections." In another place we shall refer more fully to the diseases supposed to be caused by excremental pollution of the soil.

The chief sources of excremental pollution of the soil are referable, as has already been intimated, to defects of public sewerage, to defects of house-drainage, and to defects of privies, under the latter term being included all receptacles used for the accumulation of excrement. In the absence of a system of underground conduits for the removal of excreta, some one of the many plans for the disposal of this matter upon the premises is adopted, according to the caprice or convenience of the property-owner. In some places these depositories are subject to municipal regulation, but even then the chances are that a very considerable amount of their contents finds its way into the surrounding soil. Where sewers exist, on account of faults in construction, and by being tampered with by unskilful and unscrupulous plumbers in making connections with private drains, the liquid portions of their contents ooze through their porous walls, and through cracks and joints, and cause a dangerous degree of pollution of the soil and air.

House-drains, as a source of ground contamination, are even more dangerous than the common sewers, since they are so frequently located immediately under the house, where the influence of any deficiency is more directly manifested. By unskilful construction, or by subsequent careless usage or want of repair, the filth is effused into the basement, and infiltrates the soil on which the house stands. Sewer effluvia likewise escape into the soil, where they foul the air, and, from the situation of the drain-pipes, are often drawn directly into the basement, and thence distributed all over the building by the ascensional force of the heated air.

But of all the sources of excremental pollution of the soil, none prevails to a greater extent, is more dangerous in its effects upon health, and more discreditable to sanitary management, than privies of the accumulative sort. And here, again, defective construction and subsequent mismanagement are the *raison d'être* of these nuisances, so fraught with danger to health and life.

Every out-of-door receptacle, of whatever description, should embrace all the essential features to prevent contamination of the soil and air, both in the place itself, and during the process of removal of its contents. It should be constructed of unabsorbent, impermeable material, so that no form of matter shall escape through its enclosures ; it should be so limited in size as to prevent undue accumulation of offensive matter; its use should be restricted exclusively to fluid and solid excreta, and substances applied for their absorbent and disinfecting qualities; and the removal of the accumulations should be conducted with regularity and system, and with the least conceivable agitation of the mass and exposure to the air, so that the possibility of causing a nuisance in this part of the management shall be reduced to a minimum.

In practice these conditions are frequently set at naught. In the country it is not uncommon to find no receptacle whatever, the fæcal matter and urine being deposited on the surface of the ground. The liquid parts are thus washed over the surface and soak into the ground, while the solid filth is only removed when its mere bulk becomes an inconvenience, or when there arises an agricultural demand for the material. A simple hole in the ground, with perhaps a brace to keep in place the walls of earth, is the kind of receptacle quite often used in villages and towns, and, to some extent, even in large cities. We ourselves have seen, in a prominent city, cesspits which were formed by excavating the earth so as to receive one or more sugar hogsheads, which served as the walls of the pit. The bare earth at the bottom received the filth, and designedly so, that the liquid parts might the more freely soak away into the soil. On one occasion when the ground was being excavated for building improvements, several of these filth holes were exposed to view, and the soil in their vicinity and close to dwellings revealed a condition of the most disgusting character. The liquid matter oozing from these pits had saturated and discolored the surrounding soil, and rendered it highly offensive. To what extent the health of the occupants of the neighboring houses had been impaired is not known, but the presumption is that it must have been anything but satisfactory.

In cities, wells are very commonly constructed of brickwork or masonry, with no other floor than the bare ground. They are sometimes excavated to a great depth, in order to reach a porous bed, such as gravel, the object being to secure a channel of escape for the fluid filth. The capacity of some of these wells is simply enormous. We have good authority for the statement that as much as 1,332 cubic feet of matter have been removed from a well at one cleaning.[1] It is not intended that the filth should be removed, except at very wide intervals and then only on account of some inconvenience or threatened overflow. When space is limited, privy-pits are often constructed close to foundation walls; they are even built under the basement floor, and in vaults under pavements, which are in open connection with the dwelling.

In all cities and towns, but especially in places where no sewers exist, or where they have only recently been constructed, the evil effects of this system, or rather want of system, can hardly be imagined, except by those who have made it an object of special investigation; and the contamination of soil, air, and water which it occasions, if it could be clearly traced in its influences upon the human organism, would be found to be the means of spreading some of the most common and most fatal forms of disease.

Such are the principal ways in which the soil becomes polluted from badly devised or mismanaged systems for the disposal of excreta.

Removal of Excreta.

To secure the best sanitary results, it is essential that the solid and liquid excreta from the bowels and the kidneys should be removed as rapidly and completely as possible, and, when the arrangements for a continuous and rapid outflow are unprovided, safety requires that the temporary detention of the material shall be so guarded that the danger of polluting the soil, air, and water shall, as far as possible, be prevented. In rural districts and in villages the proper disposal of excreta need not be a matter of serious embarrassment; but where dwellings are aggregated and the population is massed on comparatively small areas, the local management and ultimate disposition made of the material becomes an exceedingly difficult question to determine. The removal of the filth out of the immediate neighborhood of human habitations with completeness and dispatch, is, undoubtedly, a primary consideration, but it is also important that its final disposition should be so managed as not to cause a nuisance. This latter consideration is of great moment wherever a system of sewerage exists. Sewer-outfalls should be prevented from becoming a nuisance, and watercourses must be carefully protected from pollution. This may involve, as its consequence, the adoption of some one of the methods for the purification of the sewage, either by irrigation or filtration, or, where land cannot be obtained, by precipitation with chemical agents.

The Amount and Products of Excreta.

The amounts of solid and liquid excreta vary with the age, sex, habits of life, etc.; but, according to Parkes, the average amounts (for both sexes

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[1] The capacities of some of the privy-wells in Philadelphia, by actual measurement, are as follows: 1,785, 1,630, 1,243, 1,040, cubic feet. (Thackray.) The cesspool of the Summit House U. S. Hospital, near Darby, in use during the war, had a capacity of 5,000 cubic feet. (Andress.)

and all ages) are about two and a half ounces avoirdupois of solids and forty fluid ounces daily for each person. According to this estimate, a population of one thousand persons would pass in a year 25 tons of solid fæces and 91,250 gallons of urine. Letheby has constructed a table, based upon the investigations of Way, Lawes, and Playfair, of England, and of Liebig, Simon, Wolf, Lehmann, Fleitmann, and others on the continent, which represents not only the average proportion of solids and liquids discharged from the body daily, but also the proportions of the principal constituents of the fæces and urine passed by children and adults in the twenty-four hours.

AVERAGE WEIGHT, IN AVOIRDUPOIS OUNCES, OF THE CHIEF CONSTITUENTS OF URINE AND FÆCES PASSED BY CHILDREN AND ADULTS IN TWENTY-FOUR HOURS.[1]

CHIEF CONSTITUENTS.	MALES.		FEMALES.		Average at all ages.
	Boys.	Men.	Girls.	Women.	
URINE.	oz.	oz.	oz.	oz.	oz.
Fresh state.........	19.875	48.490	16.881	42.157	31.851
Dry matters........	0.969	2.197	0.750	1.588	1.376
Organic matters....	0.677	1.720	0.574	1.216	1.072
Nitrogen	0.166	0.481	0.161	0.326	0.284
Mineral matters....	0.292	0.477	0.176	0.372	0.332
Phosphoric acid.....	0.035	0.069	0.024	0.049	0.044
Potash.............	0.040	0.078	0.027	0.055	0.050
FÆCES.					
Fresh state.........	3.421	5.240	1.061	1.414	2.784
Dry matters........	0.879	1.112	0.282	0.376	0.662
Organic matters....	0.762	0.939	0.244	0.325	0.567
Nitrogen............	0.049	0.062	0.016	0.022	0.037
Mineral matters....	0.117	0.173	0.038	0.051	0.095
Phosphoric acid.....	0.039	0.062	0.013	0.018	0.033
Potash.............	0.014	0.023	0.004	0.006	0.012

The above estimate of the solid and liquid matters differs somewhat from those made by Parkes and Frankland, the latter placing the average daily amount of fæces per person at three ounces, and of urine at nearly forty fluid ounces. Letheby[2] has estimated the amounts contributed daily by a mixed population of 10,000 persons to be 22,659.6 lbs. of urine and 1,775.5 lbs. of fæces. From the table presented above, some idea may be formed of the relative agricultural value of the urine and fæces.

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[1] Letheby: The Sewage Question, 1872, p. 132.

[2] Op. citat., p. 133.

Numerous analyses[1] have determined it to be in the proportion of 6 to 1.

Mixed excrementitious matter, in a fresh state, has an acid reaction; but in twenty-four hours it generally becomes alkaline by the formation of ammonia. Both urine and fæcal matter, when kept separate, undergo decomposition less rapidly and retain their acidity for a greater length of time than when mixed. By the decomposition of these substances in the mixed state, ammonia and fetid organic matters are freely evolved. If water be present, and provided the temperature of the air is not too low, not only organic matters, but gases, are given off, consisting of light carburetted hydrogen, nitrogen, and carbonic acid. Sulphuretted hydrogen, usually in combination with ammonia, is almost always found in the liquid, and may be separated by the application of heat. (Parkes.)

The air of sewers, house-drains, cesspools, and privy-vaults is always more or less impure on account of the decomposition of the waste matters which they contain. It is influenced in its composition, to some extent, by the degree of ventilation and the amount and character of substances, besides excrement, present in the sewer or receptacle of filth; but, in general, it contains certain well-known gases, and also fetid organic matters, the nature of which, however, has not been determined. These gases are dangerous to health in proportion to the degree of concentration. If inhaled in large quantity and in concentrated form, they may prove quickly fatal. A number of cases are on record where men have breathed the air of unventilated old cesspools, or long-blocked sewers, with serious and sometimes fatal consequences. But in a diluted state these gases manifest their effects upon the system by a condition of general *malaise* and a depressed state of the health. The gaseous products of organic decomposition are less important than the organic matters of which sewer-air is partly composed, since these latter substances are supposed to be more specially concerned in the propagation of disease.

The air of cesspools and privy-vaults is not uniform in its character, but it usually contains, in variable quantities, sulphuretted hydrogen, ammonium sulphide, nitrogen, carbonic acid, carburetted hydrogen, and fetid organic matters. There may also be present those unknown agencies which produce typhoid fever, cholera, dysentery, and diarrhœa, and perhaps other diseases of the so-called zymotic class.[2]

The air of sewers varies in composition according to the character of the sewage, the rapidity of flow, temperature, access of atmospheric air, etc. Sewage is a complex liquid formed of solid and liquid excreta, house-slops, fluid refuse from the different branches of industry, and the washings and débris of the public thoroughfares, etc. This heterogeneous mixture contains ingredients which are always present in greater or less quantity, and these determine the characteristic properties of sewer-air. Sewer-air may be so diluted by atmospheric air as to make it impossible

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[1] Wilson: Handbook of Hygiene, 1877, p. 318.

[2] Parkes: Op. citat., p. 109.

to detect, even by chemical analysis, any but the slightest variation from the normal condition of the atmosphere. Even in ill-ventilated and badly constructed sewers the amount of variation from normal air is not great, as may be seen by reference to the table presented on the next page.

The products of the decomposition of sewage do not differ materially from the products of decomposition of the matter found in cesspools. As compared with atmospheric air, there is a diminution in the amount of oxygen and an increase of carbonic acid in sewer-air. The other constituents are nitrogen, sulphuretted hydrogen, ammonium sulphide, marsh-gas (light carburetted hydrogen), and fetid organic matters. All of these gases are not invariably present; carbonic acid and nitrogen are the most common; the other gases, when present, exist in very limited quantities.

Dr. Letheby[1] found that sewer-water (containing 128.8 grains of organic matter per gallon), excluded from air, yielded during nine weeks 1.2 cubic inches of gas per hour. In 100 volumes of this mixture there were 73.83 volumes of marsh-gas, 15.90 of carbonic acid, 10.19 of nitrogen, and 0.08 of sulphuretted hydrogen. Angus Smith[2] examined the gases evolved from putrid sewage at the bottom of the Medlock, England, and found them to contain about 88.81 per cent. of marsh-gas, 5.84 of carbonic acid, and 5.35 of nitrogen. The results of an examination of gases evolved by decomposing sewage-mud in the Seine, made by Durand-Claye,[3] show them to consist of 72.88 per cent. of marsh-gas, 13.30 of carbonic acid, 6.70 of sulphuretted hydrogen, 2.54 of carbonic oxide, and 4.58 of nitrogen and other gases. The figures represent the proportions of each gas in 100 volumes of the mixture collected without exposure to the air. Mixtures similar to these are sometimes found in long closed cesspools and privy vaults, but never in sewers properly so-called.[4]

Prof. Nichols[5] has recently made numerous examinations of the air of the Berkeley Street sewer, Boston, which is an example of the worst type of construction. The amount of sulphuretted hydrogen, and other foreign gases, was too small to be practically determined, and therefore carbonic acid was taken as the measure of impurity. In twenty-five analyses the highest amount of oxygen in any one sample was 20.90 per cent., and the lowest 20.48 per cent.; the highest amount of nitrogen was 79.26, and the lowest 78.89; the highest amount of carbonic acid was .40 per cent., and the lowest .05 per cent. The amount of carbonic acid was greater in the warmer than in the cooler months.[6]

The results of a number of analyses of sewer-air made by different chemists, which have been tabulated by Prof. Nichols,[7] are furnished on the next page.

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[1] Parkes: Practical Hygiene, p. 108.

[2] Disinfectants and Disinfection, Edinburgh, 1869, p. 25.

[3] Nichols: Sewer-Air, Boston, 1879, p. 9.

[4] Nichols: Op. cit., p. 6.

[5] Op. cit., p. 11.

[6] Normal air contains about 20.96 per cent. of oxygen, 79 per cent. of nitrogen, and .04 per cent. of carbonic acid.

[7] Op. cit., p. 10.

EXAMINATION OF SEWER-AIR.—RESULTS EXPRESSED IN PERCENTAGES.

Date.	Authority.	Locality.	Oxygen.	Nitrogen.	Carbonic Acid.	Sulphuretted Hydrogen.	Marsh gas. (CH_4).	Ammonia.	
182(?)	Gaultier de Claubry.	Paris.	13.79	81.21	2.01	2.99	.....	.....	Air in a choked sewer. (Quoted from Parent-Duchâtelet, "Essai sur les cloaques," Paris, 1824, p. 223.)
1829	Gaultier de Claubry.	Paris.	17.4	.....	....	.....	.....	.....	Smallest amount in any one of the 19 samples examined.
					3.4	.....	.....	.....	Largest amount " " " " " "
						1.25	.....	.....	" " " " " " " "
					2.3	0.81	.....	.....	Mean amount in 19 samples.
									(Quoted from Parkes' Hygiene, p. 104.)
1858	Dr. Letheby.	London.	19.51	79.96	0.53	traces.	traces.	more than traces.	(Quoted from Parkes' Hygiene, p. 104. Latham, San. Engineering, p. 205.)
1867	Dr. W. A. Miller.	London.	.....	.....	0.11	.....	.....	.....	Mean of 18 samples. Sewer without charcoal ventilators.
			20.71	.....	....	.....	.....	.....	" 6 " " " " "
			20.79	.....	0.13	0	.....	.....	" ? " " with " "
					0.31	.....	.....	.....	" 6 " (another sewer) without " "
					0.25	.....	.....	.....	" 24 " " " with " "
			20.70	.....	....	0	.....	.....	" 4 " " " " " "
									(Quoted from Chemical News XVII. (1868), p. 156.)
1870	Dr. W. J. Russell.	Paddington, Lon.	20.79	78.81	0.40	.....	.....	traces	(Quoted from Br. Assoc. Rep., 1870.)
1871	J. J. Nicholson.	Sunderland, Eng.	18.44	81.10	0.55	traces.	.....	traces }	(Quoted from Proc. Munic. and San. Engineers, I. (1873–'74), p. 50.)
1873	" "	" "	19.33	80.35	0.23	.....	.....		
1876	Drs. Wolffhügel and Bleetz.	Munich.	*	.....	0.33	....	.....	.....	Mean of sewer examinations in three sewers.
			*	.....	0.40	.....	.....	.....	Maximum of " " " "
									(Quoted from II. Bericht der Commission für Wasserversorgung, etc., Munich, 1877, p. 50.)

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* Not essentially different from ordinary air.

From all these examinations it appears that the air[1] of sewers is a varying mixture of the gases which compose the atmosphere, together with certain other gases produced by the decomposition of sewage-matter, which also vary in quantity. But these examinations furnish us with no data respecting the organic constituents—the carbo-ammoniacal vapors (Odling) and fetid organic matters—the most subtle and presumably the most dangerous elements of sewer-air. That these matters are present is apparent from the peculiar fetid smell, and sometimes they are found in large quantity: 8,000 cubic feet of the air of a house into which sewer-air had been admitted decolorized more than twenty times as much potassium permanganate as the same quantity of pure air.[2] (Angus Smith.)

Frankland[3] has shown by experiments that liquid or solid particles are not likely to be dispersed into the air from sewage-matter by the ordinary agitation of the sewage. This does not take place, as a rule, until after the setting in of decomposition; the bursting of the bubbles on the surface of the liquid scattering the minutely divided particles into the air. These minute solid particles and organic vapors are but slightly diffusable, and are therefore transported to no great distance, but soon deposit on solid objects. He draws the following conclusions from his experiments:

"1. The moderate agitation of a liquid does not cause the suspension of liquid particles capable of transport by the circumambient air, and therefore the flow of fresh sewage through a properly constructed sewer is not likely to be attended by the suspension of zymotic matters in the air of the sewer.

"2. The breaking of minute gas-bubbles on the surface of a liquid consequent upon the generation of gas within the body of the liquid is a potent cause of the suspension of transportable liquid particles in the surrounding air, and therefore when, through the stagnation of sewage or constructive defects which allow of the retention of excrementitious matters for several days in the sewer, putrefaction sets in and causes the generation of gases, the suspension of zymotic matters in the air of the sewer is extremely likely to occur.

"3. It is therefore of the greatest importance to the health of towns, villages, and even isolated houses, that foul liquids should pass freely and quickly through sewers and drain-pipes, so as to secure their discharge from the sewerage system before putrefaction sets in."

The effluvia of sewers are favorable to the growth of fungi. In a sewer which had been closed for thirty years as completely as such places can be, Ellice-Clark[4] found the walls covered with a fungoid growth of

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[1] Sewer-air and "sewer-gas" are synonymous terms, though by the use of the latter term persons are often misled into the erroneous belief that "sewer-gas" is a distinct gaseous body, having peculiar and marked characteristics of its own, by which it can always be distinguished from other gaseous bodies.

[2] Parkes: Op. cit., p. 109.

[3] Proceedings of the Royal Society, 1877.

[4] The Sanitary Record, Vol. IX., p. 99.

considerable thickness. Cunningham found bacteria in the air of sewers at Calcutta.

There is good reason for supposing that the morbific agencies which produce enteric fever, cholera, diarrhœa, and dysentery, may exist in the air of sewers. It is possible that other diseases of the zymotic class may also be caused in this way. The nature and composition of these substances are purely a matter of speculation. Neither chemical nor microscopical examination has as yet succeeded in isolating and determining the noxious matter which is probably the real cause of disease, and therefore it is impossible to say whether a particular sample of air is dangerous or not from this cause. Nevertheless it must be admitted that, in proportion as the air of drains and sewers varies from the normal standard of the atmosphere, the activity of the processes of decay of matter in the sewers, or the concentration of the products of such decay, will be manifested, and the necessity of efficient ventilation indicated. In this way chemistry may be of service in pointing out the existence of evils and in testing the efficiency of ventilation.

Methods of Removal of Excreta.

That all excreta ought to be promptly removed from the neighborhood of our dwellings is admitted, but with respect to the methods for accomplishing this object there is a diversity of opinion. It is evident that no one system can be suitable for all places, and that local considerations will necessarily influence the selection of the plan. The various plans for the removal of excreta may be conveniently discussed under the following heads:

1. The water system.
2. The dry systems.
    - Moule's earth-closet system.
    - The Goux system.
    - The ash-closet system.
3. Other systems.
    - Privy-vaults and cesspits.
    - The simple pail system.
    - The simple pneumatic system.
    - The Liernur pneumatic system.

1. *The Water System.*

The system of removal of excreta by water-carriage and gravitation through underground conduits, is undoubtedly the best for health and economy, but its successful application depends upon certain essential conditions, to which we shall presently allude. It recommends itself on account of its cleanliness, convenience, economy, and the quick manner in which the removal of the waste matters is effected. When the essential conditions on which the success of this plan depends can be commanded, it is undoubtedly the most reasonable plan to adopt. Local circumstances must always decide between this system and the dry plan. In towns where proper sewers cannot be made, or where water for flushing is deficient, or land cannot be obtained for the purification of the sewage, some one of the dry systems can be adopted with manifold advantages.

In the application of the water system, advantage may be taken of the water supplied for ordinary domestic purposes, so that but slight additional expense will be incurred for the amount needed for the closets; and, moreover, since channels must necessarily be provided to conduct away all surface-water and water used for domestic purposes, it is evident that, with but slight additional expenditure, these same channels may be so constructed as to be efficient vehicles for the removal of excreta also. To make this system a success, certain conditions must be scrupulously observed. They are summed up by Mr. Simon[1] as follows:

"1st. That the closets will universally receive an unfailing sufficiency of water properly supplied to them.

"2d. That the comparatively large volume of sewage which the system produces can be in all respects satisfactorily disposed of.

"3d. That on all premises which the system brings into connection with the common sewers, the construction and keeping of the closets and other drainage relations will be subject to skilled direction and control." And we may add:

4th. That the sewers will be properly constructed and well ventilated, and kept under efficient supervision and control.

If all these provisions be combined and properly carried out, there can be no doubt of the success of the system.

It is not surprising that discredit is cast upon this system, when local outbreaks of typhoid fever and other diseases have been clearly traced to sewers as their source. But it is fallacious to condemn a system because of the evil effects of an ill-devised, badly executed, and carelessly managed plan, supposed to exemplify the principles of such a system, but which fails to embody some of the most essential conditions of success. Such, however, is often the case. It must be admitted that sewers, as frequently constructed, are a source of danger to health. When built of improper materials, put together in an unskilful manner, they favor the escape of their fluid contents, and thus contaminate the ground and poison the water-supply. In some soils the pressure of the ground-water may be so great as to cause an influx into the sewers; but it is dangerous to trust to this fortuitous circumstance. It is more commonly the case that the pressure is exerted in an outward direction, since, when sewers are faulty in construction, they are liable to become choked up by deposits, and the sewage, being dammed up behind the obstructions, exerts this effect. When improper materials are used and the workmanship is bad, and the proper inclination is not secured, the stream of sewage is retarded, and the sewers, instead of acting as channels for the rapid

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[1] Op. cit., p. 65.

passage of the liquid filth, are converted into sewers of deposit, or "elongated cesspools," as they have been aptly called. Sewage-matter detained in this manner gives rise to the most dangerous form of "sewer-gas;" and if to these deficiencies be added the want of ventilation, and open or but slightly barred channels of communication with houses, all the conditions are present which favor general ill-health of the occupants of such houses, and which may, at any time, occasion an outbreak of disease.

Baldwin Latham[1] tells us that the early sewer-works of England were generally put into the hands of the most unskilful workmen, and little or no attention was paid to their proper construction. It was taken for granted that the sewers must sooner or later choke up from the accumulation of deposit, and therefore they were made of a size convenient for the purpose of sending men into them to cleanse them when they became obstructed. The principles upon which sewers are now made to be self-cleansing do not appear to have been well understood, at least they were not applied. The great fault of these structures arose from the fact that the size, form, mode of construction, and materials used were not suitable for the work the sewers had to perform. Bad ventilation and defective house arrangements were also prominent and serious faults of the system as then applied. The serious consequences arising from this disregard of the most essential measures aroused public attention, and started scientific inquiry into the principles which should regulate the construction and management of sewers and drains.

It has been the misfortune of this country to have had the same experience. The adoption of the water-carriage system of removal of excreta led to the use of sewers already in service for the removal of surface-water and house-water, with scarcely any or no modification at all, which were totally unfit to perform the work. But new works have been built in a similarly defective manner. So far as inquiry has been made, the system of sewerage provided in most American cities must be regarded as anything but satisfactory. The control of this important branch of public works is too often in the hands of officials unqualified by professional knowledge and experience, and grossly ignorant of the sanitary advantages to be secured. The management of the construction of sewers is frequently entrusted to incompetent and unskilled engineers and to unfaithful and careless inspectors; and from this cause even well-designed works will prove abortive.

A complete, systematic, and comprehensive plan of sewerage, which shall not only supply the immediate wants of a town, but also provide for all probable future demands, so that as each part is added it shall be in harmony with the entire system, is always an indispensable preliminary measure to the satisfactory execution and successful operation of sewerage-works. This is especially important in this country, where towns grow with great rapidity. But it is a principle that has generally been ignored. It is a very common custom to do the work piecemeal—a

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[1] Sanitary Engineering, 1877, p. 7.

section here and a section there—according to the dictation of property-owners. In Philadelphia, before constructing a branch-sewer, the consent of a majority of the owners of property fronting on the street intended to be culverted must first be obtained, and the cost of the work is assessed on all the property-holders of such street. The evil consequences of this patchwork plan may well be imagined. Most of our large cities have very bad systems of sewerage. "It is probably true," says Waring, "that no city of its age can rival New York in the defective condition of its brick sewers. They are too often badly planned, badly built, and badly kept; and they unquestionably produce a vast amount of disease and death." Philadelphia[1] has nearly two hundred miles of public sewers, built almost exclusively of brick. Most of them are constructed in a faulty manner, and without conformity to a proper system. In size they vary from three feet to twenty feet in diameter, the enormous capacity of the sewer with the latter diameter providing for the waters of Mill Creek, which frequently become greatly swollen by rains. No system of ventilation has ever been attempted. Most of the man-holes are sealed with iron covers, and the sewer inlets are all intended to be closed by water-seals. If we inquire into the condition of the pipes connecting houses with the sewer, most of them will be found to be either very imperfectly trapped, or not trapped at all. This part of the system, being subject entirely to the control of the private householder, is often defective through ignorance of its real condition, or indifference as to the results arising from its neglect. It is therefore correctly designed, well executed, and well managed, or the reverse, according to the election of the individual. So unsatisfactory an arrangement of the sewerage system of this city may account for much sickness otherwise unexplained.

In 1872 the State Board of Health of Massachusetts was instructed, by order of the legislature, to collect information concerning the sewerage of towns in that commonwealth. The report,[2] made in conformity to this order, states that "the only cities in Massachusetts now provided with a system of sewerage which can be regarded as approaching completeness are Boston and Worcester." In all the other towns it was more or less unsatisfactory. If the same inquiry were instituted in regard to other States, it is hardly likely that any more favorable reports would be received. Happily for the future welfare of the country, the people are beginning to realize the importance of a better observance of sanitary regulations, and are more willing to give intelligent support to public health measures. A new impulse has been given to sanitary progress by the diffusion of knowledge through the labors of the American Public Health Association. State boards and local boards of health are being rapidly organized throughout the country; more eminent sanitary talent is being consulted in the construction of works; blunders of the past are

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[1] See a Paper on House and Street Drainage of the City of Philadelphia, by R. Herring, 1878.

[2] Fourth Report. State Board of Health of Massachusetts, 1873, p. 32.

in prospect of being corrected; and the promise for the future is that considerations of public health will be more potent in determining the character, and in controlling the management, of these important works, which, although projected and executed mainly for sanitary objects, have hitherto often failed to embody the principles most necessary to successfully attain these ends.

Sewers.—In inhabited areas the provision of sewers, *i. e.*, underground conduits for the removal of surface-water, and the waste products from houses suspended in water, sooner or later becomes a matter of urgent necessity. In small places the open gutter is often resorted to for the disposal of house-slops as well as rain-water; but this practice, except when exclusively restricted to the latter use, can never be defended upon any reasonable grounds. It is usually a makeshift until proper and satisfactory channels for house-slops can be provided. When this material cannot be properly disposed of upon the individual premises, as is always the case where houses are collected together over a limited area, the necessity exists for the provision of public channels to carry off such waste matters. Hence most towns are provided with these public conveniences.

Sewers are used for the purpose of removing surface-water and house-slops, and the liquid refuse of trades and factories, either with or without the admixture of human excreta. They also receive a considerable amount of subsoil water. In places where the rainfall is excessive, distinct channels are sometimes provided for the rain-water, and this constitutes what is called the "separate system." When solid excreta are excluded, more or less urine is still discharged into the sewers with other waste matters. These substances, when mingled with the washings and débris of the streets, and the refuse of trades and factories, form a highly impure mixture, susceptible of putrefaction, which should be disposed of with the same care and completeness as when solid excrement forms one of the ingredients. "Investigations made in towns where the earth and ash systems prevail, as in many of the large manufacturing towns of the North of England, show that the ordinary contents of the public sewers are in all respects not less foul and offensive, and probably little less dangerous, than are the contents of those which receive all of the ordure of the town with a copious flow of water; that is to say, the kitchen-wastes and house-slops, when mixed with the wash of the streets, constitute so prolific a source of offensive sewer-gases that the night-soil is not especially marked, save as a specific vehicle for the spreading of such epidemics as are communicated by means of bowel discharges." (Waring.)

Whether such sewage should be passed into streams or not will depend upon circumstances connected with the locality. It is certainly the simplest and most convenient mode of getting rid of it; but, upon general principles, it should be forbidden until after efficient purification. When the sewage is of ordinary composition and of moderate amount, and the body of water is large and has an active current, by excessive dilution of the matter, no injurious consequences may arise. In this country it is the common practice to discharge all sewage, untreated, into the ocean or nearest watercourse, and, as yet, but few cases where serious results have been produced by this plan of disposal have been brought to public notice. The question, however, of the pollution of watercourses by sewage is beginning to elicit inquiry, and investigations upon the subject have already been started by some State governments.[1] The time will probably arrive when this matter will become a very serious one, and will have to be dealt with by the same stringent provisions as are now enforced in England under the Rivers' Pollution Act.

The composition of sewage.—Sewage-matter is made up from a great variety of substances, derived from many sources, as we have already seen. Its composition is described in the first report of the Rivers' Pollution Commissioners in the following words: "Sewage is a very complex liquid; a large proportion of its most offensive matters is, of course, human excrement discharged from water-closets and privies, and also urine thrown down gully-holes. Mixed with this, there is the water from kitchens, containing vegetable, animal, and other refuse, and that from wash-houses, containing soap and the animal matters from soiled linen. There is also the drainage from stables and cow-houses, and that from slaughter-houses, containing animal and vegetable offal. In cases where privies and cesspools are used instead of water-closets, or these are not connected with the sewers, there is still a large proportion of human refuse in the form of chamber slops and urine. In fact, sewage cannot be looked upon as composed solely of human excrement diluted with water, but as water polluted with a vast variety of matters, some held in suspension, some in solution." Sewage varies in its composition with the habits of the people, the season of the year, and even the time of day or night, and hence it is difficult to determine a standard of composition. Very numerous analyses have been made, and from these the average composition may be obtained.

CHIEF CONSTITUENTS OF A GALLON OF SEWAGE.[2]

Authorities.	Organic matter.	Nitrogen.	Phosphoric acid.	Potash.
Letheby	31.19	6.22	1.74	1.29
Hofmann and Witt	30.70	6.76	1.85	1.03
Way	29.00	6.18	1.68	2.81
Voelcker	20.00	5.67	1.00	3.00
Mean	27.72	6.21	1.57	2.03

The average amount of solid matter per gallon is 89.81 grains, of which 27.72 are organic, and 62.09 mineral.

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[1] See Reports of Massachusetts State Board of Health.

[2] Letheby: The Sewage Question, 1872, p. 138.

In addition to the finely divided particles of organic matter in various stages of decomposition, there are found in sewer-water multitudes of bacteria and other low forms of cell-life. Fungi are also present as well as myriads of ova of intestinal entozoa. (Cobbold.)

The variation of sewage from the average composition is very considerable. It is evident that a greater amount of refuse is discharged into sewers at one time than at another. At night, in many towns, the sewage is not much more than water. At some seasons it is much diluted on account of excessive use of water for bathing and other domestic purposes. It varies, too, on account of the admission of rain and subsoil water.

The amount of sewer-water in some cases is greater than the total amount of rainfall and the water supplied by public works. This excess is derived from private wells and from the water of the subsoil entering the sewers. Baldwin Latham took the average of 120 English towns, and found the average amount of water supplied by public works was 25 gallons per head. The extremes were 10 and 56 gallons per head. Where water-closets and private baths are in general use, there will always be a high rate of water consumption. All these several sources of supply must be taken into account when considering the probable amount of sewage to be dealt with.

Twenty-five gallons daily per head of population is the amount of water named by Mr. Brunel as necessary to maintain a proper flow of sewage. This may suffice if the sewers have a good inclination and are thoroughly well constructed in all particulars ; but when defective in gradient, courses, and workmanship, so as to require frequent flushing, a much larger quantity will be required.

Whether storm-waters should be permitted to pass into sewers is a question which has excited discussion. Local conditions and circumstances must be consulted in determining this point. In small towns and villages it is not advisable to provide for the underground removal of all the water of heavy rains; but in cities "all sewerage works must be calculated to convey away, either by the sewers or by storm-water overflows, or special works constructed for the purpose, the maximum amount of rain without flooding or inconvenience to the inhabitants of the district." A reasonable amount of rainfall can always be admitted with advantage into sewers intended for the removal of excreta. If the sewers be properly constructed, the admission of rain-water has the effect of scouring and cleansing these conduits in an effectual manner.

Where sewage is discharged directly into the nearest watercourse, there is no object in providing separate channels for the rainfall. There is, however, this disadvantage from the admission of surface-waters, namely, that when sewers are made large enough to accommodate the water of heavy storms, they are too large to admit of self-cleansing by the ordinary daily flow. But this difficulty may, in a measure, be overcome by adopting a shape that will best meet both of these requirements. The elliptical form is to be preferred in such cases. This mode of disposal of sewage by discharge into the nearest watercourse is generally adopted in this country; but it contravenes a well-established sanitary dictum—"the rainfall to the rivers and the sewage to the land."

The mode of disposal of sewage has a great deal to do with deciding for or against the exclusion of the surface-waters. When the sewage can be delivered at the outfall by gravitation, the objections to the admission of the rainfall are greatly lessened; but when it is required to be lifted to a considerable height by artificial power, in order to be freed from its noxious qualities before being discharged into the river, the addition of a large volume of rain-water will very materially increase the expense of the final disposal of the matter. It is, therefore, desirable to exclude as much as possible of the surface-waters in excess of the amount necessary for the proper cleansing of the sewers. All rain-water collected by the subordinate sewers, in excess of the quantity provided for in the intercepting or main sewers, may be passed into the river by means of "storm overflows." The occasional discharge of the excess of storm-water into the river, during a heavy rainfall, cannot materially impair the quality of its water.

It has been urged as an objection to the admission of the surface-waters that the sewage proper is diluted and deteriorated thereby, and its economic treatment greatly imperilled. This objection is based upon the assumption that the surface-drainage is comparatively pure, and should, therefore, be conveyed to the ordinary watercourses of the district. But it would appear from the investigations of the surface-water of London, made by Professor Way, which ought to hold good for all crowded localities, that their manurial value is equal to that of ordinary sewage. He says that "so far as London is concerned, and considering only the composition of the liquid which reaches the sewers in the time of rain from the streets, it seems pretty certain that it would be as valuable in a manurial point of view as the ordinary contents of the sewers. There would seem to be no reason. therefore, to exclude such waters on the ground of the dilution and deterioration of the sewage, to which they might be supposed to lead." If such be the case, then the whole of the surface-water of a crowded locality should be disposed of in the same manner as the ordinary sewage-matter. This difficulty may be overcome by admitting into the sewers rainfalls which are small in amount, and, in time of excessive downfall of rain, only the first or foulest portions; the last water contributed by heavy storms being comparatively pure, may be suffered to pass directly into the river by storm overflows.

In many sea-side towns, and in districts where the outfall sewers are tide-locked, it may be proper to construct special works for the purpose of conveying off the rainfall; but this is a case for decision upon conditions largely connected with the locality.[1]

As before remarked, the purpose of a system of sewerage is to remove certain waste products as rapidly and completely as possible, so that during their passage and at the place of final disposal, neither the air, water,

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[1] Bailey Denton: San. Engineering, 1877, p. 157.

nor soil shall be rendered impure. In the accomplishment of this purpose, sewers perform a most important part. They are not mere conveniences, as might be supposed from the manner in which they are often constructed. They have a great sanitary mission to carry out, and the more steadily this object is kept in view the more satisfactory will be the results obtained. A sewer cannot properly perform its functions unless made to conform to certain essential conditions. These have been clearly and correctly stated by Mr. Waring as follows :

"1. It must be perfectly tight from one end to the other, so that all matters entering it shall securely be carried to its outlet, not a particle of impurity leaking through into the soil.

"2. It must have a continuous fall from the head to the outlet, in order that its contents may 'keep moving,' there being no halting to putrefy by the way, and no depositing of silt that would endanger the channel.

"3. It must be perfectly ventilated, so that the injurious gases that necessarily arise from the decomposition of matters carried along in the water, or adhering to the sides of the conduit, shall be diluted with fresh air, and shall have such means of escape as will prevent them from forcing their way into houses through the traps of house-drains.

"4. It must be provided with means for inspection, and, when necessary, for flushing.

"5. Its size and form must be so adjusted to its work, or to its flushing appliances, that the usual dry-weather flow may be made to keep it free from silt and organic deposits."

It is necessary that all of these particulars should be faithfully and efficiently carried out. The neglect of any one of them not only defeats its own special end, but interferes with the operation of all the rest, and, to some extent, renders nugatory the sanitary advantages which their united observance alone can secure.

A work of this kind is not intended to furnish all the details of sewer construction; it will suffice to set forth the principal features of the system, with the objects which they are intended to accomplish.

Construction of sewers.—In the construction of sewers it is of primary importance that the work should be thoroughly well done, according to a well-arranged and systematic plan. The workmanship, as well as the materials used, should be of the best quality. To secure these objects, the services of a thoroughly competent engineer should be employed; and the work, as it progresses, should be subjected to the rigid scrutiny of qualified inspectors. Such advice would be superfluous if it were not too often the case that these important works are intrusted to engineers of very indifferent ability, and their supervision to inspectors sadly deficient in the qualifications which such officials should possess.

In arranging a plan for sewerage-works, one of the most important points to be considered is the regulation of the size of the sewers. This will depend upon the amount of sewage proper, as influenced by the habits, occupation, and trades of the inhabitants of each locality, the amount of ground-water that may be accidentally or designedly admitted, and the quantity of rainfall. The quantity of ordinary sewage varies with the season and with the hour of the day. Provision must be made for its maximum outflow, and, in addition thereto, for the maximum quantity of storm-water, when such is admitted into the sewers. The influence of the grade of the surface in determining the rapidity with which the rainfall is discharged into the sewers claims attention.

Mr. Shed, of Providence, says:[1] "The capacity of sewers to carry water depends mainly on their sectional area—if of proper form—and the rate of fall. In order to render sewers as nearly self-cleansing as possible, they must, as before stated, be adapted, in size and inclination, to the ordinary flow of sewage, so far as to keep up a velocity sufficient to carry on all light matters, and to leave only so much heavy matter as will be finally carried along by the scouring effect of the storm-waters."

As a general rule, sewers are made too large, thereby defeating the very object they are intended to promote. The ordinary stream of sewage being small in proportion to the size of the sewer, and being spread over a large surface, the velocity of the current is so impeded by the bed and sides of the channel, that the solid matters become deposited and accumulate until the sewers become completely choked up. The velocities required to render sewers self-cleansing have been variously estimated by different writers. Mr. Wicksteed showed by experiments that, for the removal of heavy sewage-matter, when the sewer was running full, or nearly so, a mean velocity of 137½ feet per minute would be required. Bailey Denton considers a mean velocity of 150 feet per minute as necessary for the proper flow of ordinary sewage. Other observers have placed the figures a little higher. Baldwin Latham says, that in no case should the velocity be less than 120 feet per minute, and in the generality of cases it should be much greater. He says "that in order to prevent deposit in small sewers or drains, such as those of six-inch or nine-inch diameter, a velocity of not less that 3 feet per second should be produced. Sewers from 12 to 24 inches diameter should have a velocity of not less than 2½ feet per second; and, in sewers of larger dimensions, in no case should the velocity be less than 2 feet per second. In order to maintain these velocities in sewers, it is absolutely requisite that a certain rate of inclination should be secured; thus small sewers will require a greater rate of fall than large sewers; and large sewers, on the other hand, must have provided a much larger volume of fluid, so that proper velocity through them may be maintained."[2] The velocity of the current is greater the further the particles of the liquid are removed from the sides and bottom of the channel. Hence the velocity at the bottom of the sewer is much less than the mean velocity which we have been considering. Velocity diminishes greatly with the depth of the stream flowing through the channel; and, consequently, when the stream is the smallest,

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[1] Waring: Sanitary Drainage, etc., 1878, p. 130.

[2] Sanitary Engineering, 1877, p. 8.

and of the least depth, there is a great tendency for matters suspended in the sewage to be deposited. For this reason the smaller sewers, which carry but a small quantity of sewage, should have a greater inclination than the larger sewers, in order to maintain a velocity of flow necessary to make them self-cleansing. The proper inclination of various sized sewers may be ascertained by consulting works on sanitary engineering.[1]

A sewer designed with the proper rate of inclination to render it self-cleansing, when running full or half full, may become a sewer of deposit, if the volume of sewage is ordinarily small in proportion to the capacity of the channel. This difficulty is often encountered as the result of making sewers sufficiently capacious to accommodate storm-waters. If possible, the size of the conduit should be proportioned to the volume of sewage; but when this plan cannot be adopted, that form of sewer should be selected which will give the greatest velocity to the ordinary volume of sewage. The oval form of sewer is to be preferred when the volume of sewage-matter is subject to fluctuations. It has the advantage of securing greater depth of sewage and less surface than the other forms, as will be seen by Fig. 13.

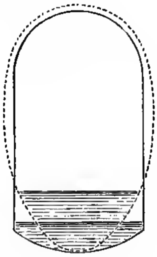

FIG. 13.

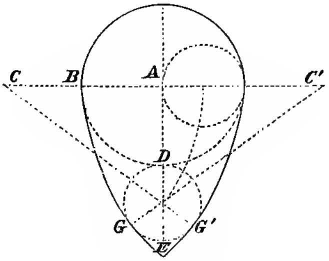

FIG. 14.

Various sectional forms for sewers have been adopted from time to time, but those considered most desirable, and which are most commonly used, are the circular and the egg-shaped. The forms vary in the resistance which they offer to external pressure, but all forms can be so constructed as to insure stability. The main consideration which influences the selection of the shape of a sewer relates to the velocity of the flow of sewage. That shape should be adopted which will secure the maximum velocity to both the maximum and minimum flows. The form which most fully meets these requirements is the egg-shaped form, Fig. 16. When the volume of sewage ordinarily flowing through a sewer is small in proportion to the capacity provided, the lesser area of the wetted perimeter[2] and the greater depth of sewage, afforded by the egg-shaped sewer, give a greater velocity, and, therefore, a greater cleansing power to the flow, than could be secured by the equivalent circular sewer, while, at the same time, equal facility is furnished for larger volumes of sewage.

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[1] Sanitary Engineering by Baldwin Latham, also by Bailey Denton.

[2] "That portion of the channel in a sewer or watercourse which is touched by the water."

The form of egg-shaped sewer considered the best by Latham, and approved by Bailey Denton, is that represented by Fig. 14. "In this form the horizontal diameter is two-thirds of the vertical height, the radius describing the invert being one-fourth the horizontal diameter. The semicircle drawn on the horizontal diameter becomes the upper portion of the sewer, while the segment drawn on the radius forms the invert. By continuing the horizontal diameter half its length on each side, points C and C′ are gained from which an arc may be struck for the sides to perfect the egg-shaped form."[1] Other modifications of the oval form have been adopted. That by Mr. Hawksley is perhaps one of the best; it has the advantage of easier construction, but is not so well adapted for sewers in which the volume of sewage is subject to constant variations of flow as the one recommended by Mr. Latham.

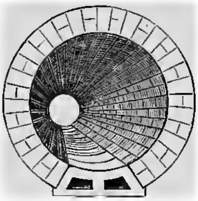

FIG. 15.

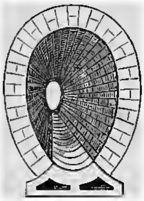

FIG. 16.

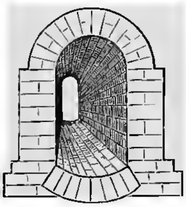

FIG. 17.

The circular sewer, Fig. 15, is to be preferred when the volume of sewage is large and maintains a tolerably uniform flow; and, moreover, it is cheaper, since it affords "the greatest sectional area for the amount of wall required, and, therefore, the greatest capacity for discharge."

Sewers with perpendicular sides, having an arched roof and a flat or hollowed invert, as illustrated by Fig. 17, are sometimes used; but they are inferior to the forms mentioned above, Figs. 15 and 16, and are only adopted in exceptional cases.

In constructing sewers designed to carry excreta, it is of paramount importance that they be made water-tight. This object is frequently defeated by the selection of faulty materials, or, when the materials are of the proper kind and quality, by constructing the works in a defective manner. The materials generally selected are bricks, stone, stoneware and earthenware, concrete, and sometimes iron. It is advisable always to use the best possible materials, since they are eventually the cheapest and altogether the most satisfactory. Sewers of more than eighteen inches internal diameter are usually constructed of bricks set in cement or hydraulic lime mortar. They should be hard, well burnt, and well shaped. Smoothness of surface is a desirable quality, especially for such as are used for the inner lining.

The inverts of sewers of moderate size are generally made of blocks constructed of terra cotta, stoneware, or fireclay, glazed on their inner

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[1] Bailey Denton: San. Engineering, 1877, p. 188.

surface. They facilitate the work of construction, are durable, and, by presenting a smooth surface, offer the least frictional resistance to the flow of sewage. The continuous openings in these blocks form a simple mode of getting rid of subsoil-water. The usual forms of invert blocks are sketched at Figs. 18 and 19, and are shown in position in Figs. 15 and 16.

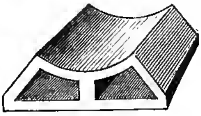

FIG. 18.

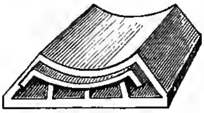

FIG. 19.

Sewers are sometimes constructed entirely of concrete. This material is highly appreciated, and is now being more commonly used. It has the advantages of durability and economy. Sewers formed of a slight ring of brickwork, surrounded by concrete, are preferred by Denton to all others. Concrete sewers may be made of bricks constructed of concrete and laid like ordinary brickwork, or they may be formed of compressed blocks of concrete. These are both excellent forms, but they are more expensive than brick sewers.

Small sewers and house-drains are generally made of stoneware or earthenware pipes. For the smaller conduits it is advisable to select the circular form. "The best quality of pipes for sewers are those made of a vitreous, imperishable material of sufficient strength to resist fracture, having toughness enough to resist shocks, being tenacious, hard, homogeneous, impervious in character, uniform in thickness, true in section, and perfectly straight, uniformly glazed both inside and outside, free from fire or other cracks, and when struck should ring clearly." Porous material is unsuitable, since it becomes saturated with filth, is less able to resist pressure, and is more easily affected by frost and the chemical action of sewage. The best pipes are the salt-glazed, as this process requires a more thorough burning than is needed for lead or glass glazing, and therefore secures a harder and more durable material.

The pipes most commonly used are the simple socketed pipes, with spigot on one end and socket on the other.

In laying sewer-pipes care should be taken to have a well-regulated fall, and that each pipe shall have a uniform bearing throughout the entire length of the sewer. To secure a true position and a firm support for the pipes, the bottom of the trench should be hollowed out to receive each joint. The greatest care should be exercised in adjusting and securing the joints.

In all cases the joints should be caulked with tarred gasket, and afterward finished with cement or clay in the usual manner.

Great damage may be done to pipe-sewers by the entrance of roots. This may be prevented by enveloping the sewer in concrete. Asphalt used for jointing is said to be equally efficient in preventing the entrance of roots of trees.

Various modifications have been made in the form of pipes used in the construction of drains or small sewers. One of the early modifications is the so-called opercular or lidded pipe, represented by Fig. 20.

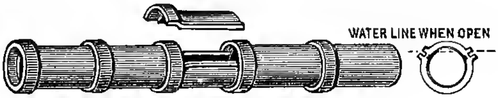

FIG. 20.—Opercular, or lidded pipe.

The advantage of this arrangement is, that it facilitates the examination of the interior of the pipes and the removal of obstructions, and, also, that it affords a means of effecting a junction with pipes that have already been laid, without disturbing the bed of the sewer. The ordinary flow of sewage will be below the line of junction of the lid with the pipe, which, however, may be made sufficiently tight to prevent any leakage. Another form of access-pipe is that introduced by Mr. Jennings, and represented at Figs. 21, 22, and 23. The pipes are "plain at both ends, and laid in chairs (c) similar to the metals of a railway, each pipe being kept 6, 9, or 12 inches *apart*, according to their diameter." The top part of the chair, which is called the saddle-piece, Figs. 22 and 23, can easily be removed, so as to afford a thorough inspection of the pipes, and, in case of stoppage, facilitate the removal of obstructions through the openings, SS, without in any way disturbing the invert or general drain. "In laying out new districts, and in the formation of new roads, streets, etc., the drainage may be laid complete without the introduction of the ordinary junctions, or saddle-pieces, Fig. 23. When house is added to house, and it is desired to effect a junction with a finished line of pipes, the workman has only to raise one of the plain short pieces, Fig. 22, and substitute for it a similar short piece having a junction on it of the required size, Fig. 23, which, by reversing, is applicable to either side of the street, and again completes the line of street drain."

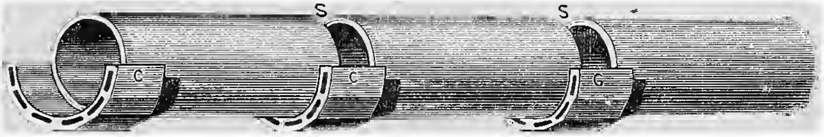

FIG. 21.—Jennings' access-pipe.

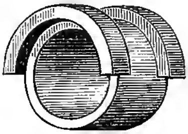

FIG. 22.

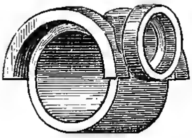

FIG. 23.

According to Waring, the best pipe known in this market is the Scotch; there is also excellent pipe to be had of domestic manufacture. Unfortunately the best quality of pipe is not always the most popular. The inferior grades find a ready sale, because they are cheaper. An immense quantity of this defective material is annually used for the drainage arrangements of the so-called "bonus" houses, which are a disgrace to our large cities. Citizens are deceived by entrusting so important a matter as the construction of private drains to incompetent and unfaithful workmen, and builders purposely slight the work without detection, in the absence of proper inspection. A thorough and systematic inspection, under proper authority, of all private drainage arrangements, would tend greatly to remedy this great evil, and should be insisted on by all local health boards.

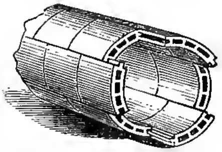

FIG. 24.—Segmental stoneware sewer.

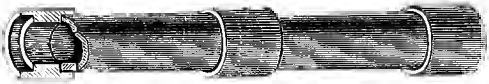

FIG. 25.—Stoneware drain-pipe.

Sewers are sometimes made of blocks of stoneware of various shapes. Fig. 24 represents a segmental stoneware sewer, which has been used in England with success. The advantages of this kind of sewer are, that it is strong, easily put together, and is exceedingly durable.

An excellent stoneware drain- or sewer-pipe is made in Chester, Pa., which possesses the advantages of strength, durability, accuracy of coupling, and smoothness of internal surface. The pipes, as shown in Fig. 25, are plain at both ends, and are united by a double-socket coupling which fits very accurately. The joint is really the strongest part of the pipe. Each piece is provided with a bed almost its entire length, which gives it additional strength. The pipes are made in iron moulds, and therefore have a perfectly smooth interior bore, which facilitates the passage of their contents. Their strength is such as to resist rupture, either from internal pressure or from weight applied externally, and the materials of which they are composed resist the chemical action of sewage and the effects of frost. The oval form is well adapted for moderate-sized sewers.

Iron-pipes are used in special cases, *e. g.*, when sewage has to be conveyed across rivers or from one side of a valley to another. Special care should be taken to have such pipes of sufficient thickness to resist all strain. Iron-pipes are often employed for private drains. They should be carefully tested before being used, that no sand holes or other defects escape notice. Cast-iron soil-pipes, especially when *porcelain lined*, are, as a rule, superior to all other kinds.

Sewers should be laid in perfectly straight lines, and should have a true and even bearing from point to point. If curves cannot be avoided, the sewer should have a little extra fall in the bend to compensate for friction.

Wherever sewers join, or wherever there is a change of direction or of gradient, man-holes or lamp-holes should be provided in order to afford convenient access for the purpose of inspection, flushing, and the removal of obstructions. These shafts also supply a means of ventilation.

The junction of one sewer with another, or of house-drains with sewers, should be made by curves in the direction of the current of the main sewer. Junctions made at right angles, or opposite the entrance of other sewers, interfere with the velocity of the flow and favor deposits. House-drains, and branch sewers connecting with main sewers, should have their junctions made just within the water-line, but not so low as to leave their inverts upon the same level. When made in the crown of the arch of the sewer, they have the effect of impeding the velocity of the current, and, thereby, of causing the formation of deposit both above and below the line of junction, as is shown by Fig. 26. By placing the junction below the water-line, house-drains are provided with a water-seal more or less effectual in excluding the entrance of sewer-air.

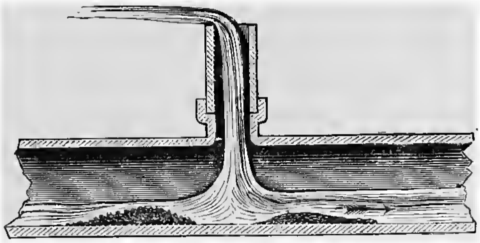

FIG. 26.—Right-angled junction entering at the crown of sewer-pipe, a cause of deposit.

Man-holes and lamp-holes.—Man-holes and lamp-holes are necessary adjuncts to every complete system of sewerage. They are constructed for the purpose of examining and cleansing the sewers, and they also act as ventilating shafts. They should be located at points of deviation from a straight line. Man-holes are simply shafts, usually built of brick, by which men can descend from the street surface into the sewers, or to the sewer level. They either open above the sewer or at its side; the former plan is the simpler of the two, and is the one most commonly adopted. Lamp-holes are small shafts made of stoneware or vitrified pipes, and are used for the purpose of lowering a lantern into the sewer, in order that the person at the nearest man-hole may discover any obstructions existing in that part of the sewer intervening between the two points.

Man-holes and lamp-holes are usually provided with wrought or cast-iron covers. Strong iron gratings are to be preferred, as they allow of the ventilation of the sewer. It is recommended that a dirt-box be used below the grating to catch any earth that may pass through the openings. The arrangement adopted by Mr. Denton is shown at Fig. 27. This provision can hardly be necessary, as very little dust or mud is carried into the sewer through these openings, and, besides, it is objected to on the ground that it interferes with the ventilation. However, if the provision is deemed advisable, the plan approved by Mr. Waring had better be adopted, namely, "to make a recess or catch-pit in the bottom of the sewer, under the man-hole, to retain any earth entering through the grating." When ventilating side chambers are provided, the cover of the man-hole may be made solid, and any dirt passing through the grating of the ventilating chamber will be retained by the catch-pit at its bottom.

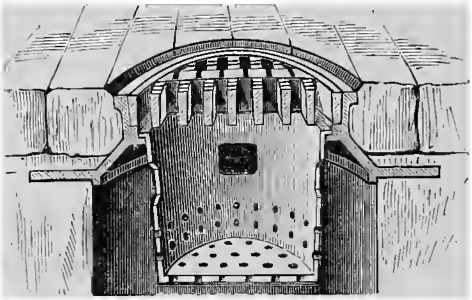

FIG. 27.—Man-hole cover, with dirt-box attached.

Street-gullies and traps.—Gullies are openings placed at the corners of streets, or elsewhere, to receive surface and waste water, slops, etc. They should be provided with catch-pits below the point of overflow, of sufficient depth to intercept and retain the solid materials carried in by the surface-water. In order to prevent the escape of sewer-air from these street inlets, an efficient means of trapping should be adopted. Various devices have been introduced to accomplish this object. Those most generally in use depend upon water as the means of trapping. A simple form of water-trapped gully is shown at Fig. 28. All trapped gullies should be

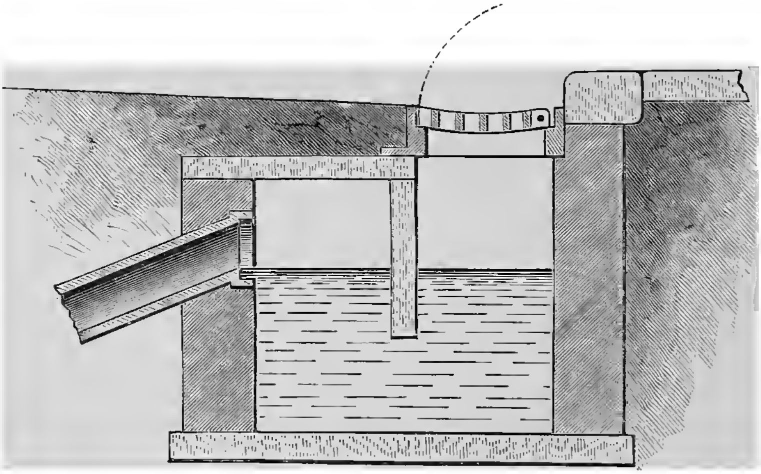

FIG. 28.—Section of a trapped street-gully.

made thoroughly water-tight, otherwise they are liable to become untrapped by leakage. Should the water-line be lowered during the cleansing of the catch-pit so as to unseal the trap, care should be taken to refill the basin. It is urged as an objection to the use of water as a means of trapping that it is apt to be evaporated. This disadvantage is readily overcome by filling the receptacles with water from the public hydrants, a duty which may be entrusted to policemen. Street gutters will be the better for such flushing in dry weather. The entrances to gullies should be protected by strong iron gratings. Their use is very obvious.

Tidal valves. — Whenever sewers empty into the sea, or into a tidal stream below high-water-mark, the outlets must be protected by means of flaps, or valves, to prevent the water from rising in the sewers, and also to exclude the wind, which, in time of storms, may force the sewer-air through badly trapped house-drains. They are usually made of iron, and are so balanced as to yield to the slightest internal pressure, and close readily and tightly by the least amount of pressure from without. Two kinds of self-acting tide-valves are shown at Figs. 29 and 30. (Denton.)

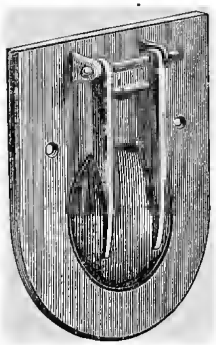

FIG. 29.

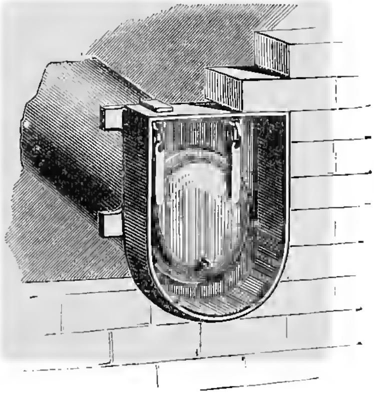

FIG. 30.

Flushing of sewers.—We have seen that, in order to prevent sedimentary deposits in sewers, a certain velocity of flow must be maintained. But as every sewer has, more or less, an intermittent flow, the velocity required to make them self-cleansing cannot always be secured, and hence it is a difficult matter, in practice, to keep sewers thoroughly cleansed and in good working order, without some additional means for removing the sediment and for washing away the slimy matter which collects upon their sides and crown. This is especially necessary for sewers which have been badly constructed, or which, from too little fall, too great size, or want of proper flow, are unable to carry forward the solid matters suspended in the sewage. Arrangements for flushing are, therefore, absolutely necessary to remove these deposits and keep the channels free from obstructions. The object of these arrangements is to discharge a body of water, or sewage, at a velocity, and for a length of time, sufficient to remove any deposits, and thoroughly wash the walls of the sewer. The volume required is, according to Latham, considerably less than the full discharge of the conduit. Various plans have been adopted for the purpose of flushing sewers. The simplest of all is that in use where no special appliances exist. It consists in periodically turning on a number of public hydrants, by which a considerable body of water is simultaneously discharged into the sewers of a district through the different street gullies, or inlets. The effect is similar to that produced by a heavy fall of rain.

Sewer-water is sometimes used for flushing purposes. It is held back by flushing-gates, and then, upon being suddenly liberated, produces a scouring effect.

These gates are made to fill the entire sectional area, or only a part of it. The half and three-quarter flushing-gates have this advantage, that if not opened at the proper time, the sewage will pass over their upper margin without causing any damage. A half-gate is shown at Fig. 31.

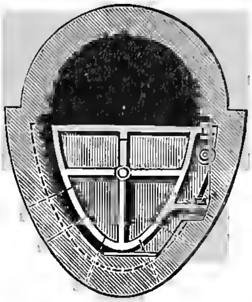

Fig. 31.—A half flush-gate or valve. (Denton.)

Self-tilting flushing apparatus, similar to the self-acting tumblers sometimes used for water-closets, are very serviceable for small sewers in which the ordinary flow is not sufficient for cleansing purposes, or where flushing-gates are not applicable. The tank is set on trunnions directly in the line of the flow of sewage, and, when filled, turns over by its own weight, and after thus suddenly discharging its contents into the sewer below, rights itself. The same operation is repeated, more or less rapidly, according to the flow.

Reservoirs are made use of for collecting sewage, storm-water, subsoil-water, or water from the public hydrants, and suddenly discharging it into the sewers. Water from neighboring streams may be utilized for flushing purposes. It may be collected in basins, and conducted into the sewers by means of pipes provided with sluice-gates, or with valves regulated by a lever and weight.

In flat districts, advantage may be taken of the tide in collecting river water in reservoirs at high tide, and discharging it into the sewers at low-water mark. By this plan the sewers may be kept thoroughly cleansed with moderate expense.

In flushing sewers, the operation is generally commenced at the lower parts of the district; but this will depend upon the amount of water at command.

In some systems of sewerage, flushing arrangements are provided at every man-hole and at the head of each line of sewers. The various appliances suggested may be used singly, or in combination, according to the requirements of each particular case.

Flushing-tanks placed at the head of sewers may be constructed in the manner represented by Fig. 32. They are closed below by penstocks, which are raised by a rack and worm-wheel motion, whenever it is required to suddenly liberate the body of water contained in the reservoir for flushing purposes. These reservoirs may also be used as man-holes and as ventilating shafts.

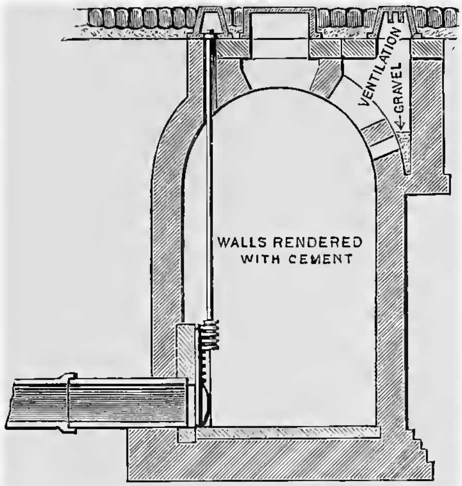

FIG. 32.—Flushing tank. (After Tarbotton.)

Ventilation of sewers.—Sewer-ventilation is even more important than sewer-flushing, though neither the one nor the other can safely be dispensed with in any system of sewerage. Unfortunately the means of carrying into effect this most important sanitary measure have not yet been determined with entire satisfaction. Much, however, has been accomplished in this direction.

In order to prevent the concentration of sewer-air, relieve pressure, and reduce to a minimum the decomposition of organic substances contained in sewage, it is of the greatest importance that openings communicating with the sewers should be provided, to afford an outlet for the foul gases, and secure the free admission of atmospheric air. No system of sewerage, however well designed, and however carefully the plans may be carried into effect, can be depended upon to fulfill its sanitary mission, unless there be combined with it a thorough system of ventilation. By ignoring this principle, the town of Croydon suffered from repeated outbreaks of enteric fever. "The early sewer-works were designed on the principle that all matters were to be so rapidly discharged from the sewers, and the sewers flushed with such a copious supply of water, that decomposition could not take place, and, therefore, it was thought that 'sewer-gas' would never be present; but, in practice, this theory was not found to be borne out; and it is a remarkable coincidence as to the cause of the frequent outbreaks of fever in Croydon (which took place at certain intervals until the year 1866, when the sewers were thoroughly ventilated), that diseases which formerly made their haunt in the low-lying districts were transferred, after the completion of the drainage-works, to the highest or best portions of the town, thereby establishing the fact that the presence of the disease in the high localities was due to something carried in the air of the sewers, which, in obedience to a natural law, accumulated in the highest part of the district." Since the introduction of ventilation there has been no epidemic of fever until very recently (due to defects which were promptly remedied); and the mortality has decreased, so that the death-rate rarely exceeds eighteen per thousand of population. The ventilation of the sewers of London, though not by the most approved method, is asserted, by competent authority, to have been attended with good results, as indicated by the small death-rate of that city.

The higher temperature of the air of houses, especially when artificially heated, favors the entrance of sewer-air through the drain-pipes. The pressure of the atmosphere upon traps within houses being less than the pressure upon traps outside, the air of unventilated sewers will naturally find its most convenient outlet through the pipes communicating with the interior of houses.

There are forces at work within an unventilated sewer which tend to drive the foul air into houses. Heat is one of these forces. The hot water discharged into sewers from baths, kitchens, and manufacturing establishments, affects the pressure of the air. The repeated expansions and contractions of the air, caused by the admission of hot and cold water, develop a force which no trap can resist, unless free ventilation is established.

The air of sewers is displaced, sometimes with great force, by the constant fluctuation in the volume of sewage. Unless openings are provided to accommodate these changes in the pressure of the sewer-air, the effect is directly exerted upon the house-traps. When the pressure is increased by the rise of the sewage, the foul air is expelled through the traps; and when the pressure is reduced by the fall of the sewage, the traps are forced in a reverse direction. In either case they may be left open to the free passage of sewer-air for a variable length of time. Storm-water, when discharged into sewers, has the effect of displacing the air with like results. When sewers empty into the sea, or tide-rivers, they may become tide-locked, and, by damming up the sewage, force the sewer-air through weak traps.

Parkes contends that the tide rises so slowly, and the air is displaced so equably and gradually, that no appreciable movement can be detected, and that, therefore, any well-arranged trap will be able to resist the pressure. This is true, if outside ventilation is provided.

The discharge of exhaust steam into sewers increases the pressure and tends to force the air into houses, unless a vent for its escape exists.

When the outlets of sewers are exposed to the action of the wind, the sewer-air may be driven forward into houses, if no outside channels of escape are provided. Latham recommends that, even in ventilated sewers, every outfall should be protected so as to control the currents of air.

Barometric changes also influence the pressure of sewer-air.

Of the various plans proposed to effect the ventilation of sewers, very few are of much practical value. Attempts have been made to secure ventilation by drawing the air out by mechanical appliances, but with only limited success. Experiments have been tried with shafts and furnaces specially contrived for the purpose, but the results have been far from satisfactory. It has been proposed to make use of the chimney shafts of manufactories, and this plan has been tested to some extent. The conclusion in the matter has been adverse to the adoption of this method as a general one for promoting ventilation. Another plan, which depends for its efficiency upon the ascensional force of the sewer-air, consists in the use of special metallic pipes connecting with the crown of the sewer, and carried underground to the external walls of the buildings, and thence upwards some distance above the eaves. Combustion by means of large furnaces has also been tried, the sewer-air being conducted into the ash-pit and through the furnace-fire.

Ventilation by rain-water pipes has been recommended. This method likewise has its disadvantages. When ventilation is most needed, as during the time of storms, these pipes are filled with water and are therefore inefficient. Moreover, being almost invariably connected with the house-drains whose terminal openings in the sewers, if not ordinarily below the water-line, are certainly so during a heavy rainfall, these pipes fail to afford an outlet to the confined gases when such a vent is most required. There is still another and a very serious objection to this plan. When the sewer-air is discharged from rain-water pipes under the eaves of houses, it may find access to sleeping apartments, with the most disastrous consequences. At Croydon this system was rigorously enforced for several years, during which time the death-rate of the district increased. In 1866 it was abandoned and a better system of public ventilation substituted, when the death-rate fell again to its former figure.

It has been suggested that lamp-posts and telegraph poles be altered in their construction so as to serve as ventilators. In Liverpool small shafts have been fitted with Archimedean screws for the purpose of exhausting the air from the sewers. Parkes states that these screws appear to act, but not to such an extent as to warrant the expense.

As all these schemes have been only partially successful, it is not surprising that attempts have been made to neutralize the poisonous constituents of sewer-air, or to prevent their formation. It was thought, at one time, that sewers could be made so thoroughly self-cleansing that ventilation would not be required. This theory has proved delusive, as has been exemplified by the works at Croydon. It has been proposed to deodorize or disinfect all matters either before being passed into the sewers, or during their transit through these channels. This plan is not only expensive, but it has been found to be impracticable. The use of carbide of iron, lime, and other substances in sewers, for the purpose of absorbing and destroying foul gases, has been recommended, but the plan of their application is as difficult as that suggested for the introduction of gases, such as chlorine or sulphurous acid gas, which are intended to destroy the noxious properties of the sewer-air.

Charcoal has been used for the same purpose, and as long ago as 1858 Mr. Chisholm proposed the application of electricity or galvanism to the vitiated and noxious gases contained in confined places, as in sewers, drains, and the like, in order to decompose, disinfect, and destroy them, by producing or disengaging ozone.

All these methods for preventing the formation of sewer-gas, or for destroying its noxious qualities, possess but little merit, and, unless combined with a proper system of ventilation, are worthless.

What then is the best plan for the ventilation of the public sewers? In determining this question the essential points to be borne in mind, are, as stated by Mr. Latham:

"1st. That the system shall be simple in its operation and not likely to get out of order, and that it shall be independent of uncertain mechanical aid.

"2d. That it shall admit of the expulsion of all sewer-air, and the supply of fresh air at all periods.

"3d. That the escaping gases shall be so diluted with atmospheric air as to be rendered harmless, or that they shall be destroyed or arrested.

"4th. That the system shall not impede natural ventilation.

"5th. That it shall not be costly in execution or maintenance."

The method of ventilation by means of man-holes and lamp-holes in the centre of the street is the one which most completely fulfills these conditions. The openings should be large and sufficiently numerous to insure complete ventilation of every part of the sewer. In the lower districts they should be placed nearer together than in the higher parts of the town. "In no case in which houses are connected with the sewers," says Latham, "should the distance between ventilators be more than 200 yards."

These openings should always be placed in the centre of the street, so that the escaping air shall be diluted as much as possible before reaching the sidewalk. Thorough dilution is the great safeguard; if this be secured, sewer-air is robbed of its noxiousness. Where the streets are very narrow, shafts had better be used.

The sewer inlets, or gullies, when placed at the edge of the sidewalk, as they usually are, should always be efficiently trapped. A man-hole provided with a grating to act as a ventilator is represented by Fig. 33. Beneath the grating, a perforated iron dirt-box (illustrated by Fig. 27) is fixed, to intercept any substances that would otherwise fall into and obstruct the stream of sewage. This form of man-hole and ventilator is adopted by Mr. Denton, from whose work the illustration is copied.

In order to regulate the escape of sewer-air, and prevent its passage from the lower to the higher districts, it is usual to place a lightly-balanced hanging valve, or flap, in front of the outlet into the man-hole. This plan does not interfere with the flow of sewage, while it prevents the further passage of the air along the sewer, and compels it to escape through the ventilating shaft. This arrangement is shown in Fig. 34.

For years past charcoal has been used in sewer-ventilators as an agent well fitted to absorb and destroy the escaping gases and impurities. It is undoubtedly a most efficient article, and it has the additional advantage of cheapness. But its use is objected to on the ground that it obstructs the free circulation of air, which, after all, is the great object to be attained. The charcoal becomes saturated with moisture and covered up with dust from the streets, and is thereby rendered inoperative, so far as its special action is concerned, and, moreover, it forms a barrier to the circulation of air into and out of the sewer. For these reasons the plan is gradually being abandoned, though it still has some firm advocates, Mr. Latham being among the number. The misuse of charcoal ventilators is, doubtless, one reason why these appliances have come into disfavor. Latham says "that it should be borne in mind in using charcoal, that whenever it is used it should be so arranged as not to obstruct natural ventilation, and it should be kept perfectly dry, for it loses its power if it gets saturated with water." These are the difficulties which in practice it is not so easy to overcome, and hence the disposition to dispense with the use of charcoal in street sewers.

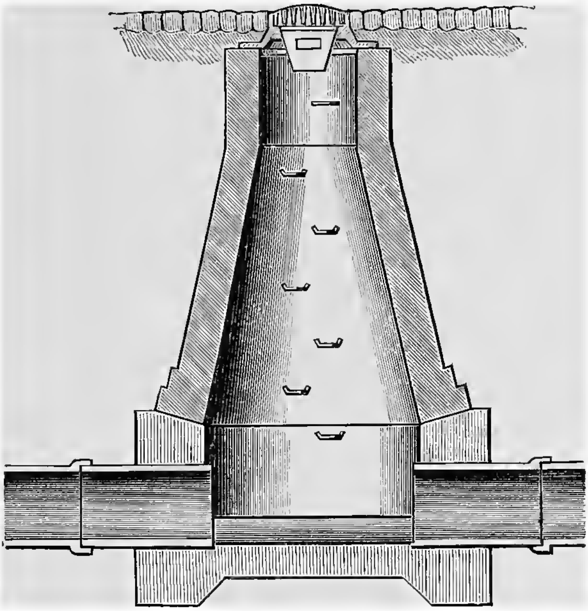

Fig. 33.—Man-hole for pipe-sewers.

Fig. 34 represents the plan adopted by Mr. Rawlinson, and which has frequently been brought into use. The man-hole is sealed with a movable iron cover. Across the shaft are two trays of charcoal, through which the sewer-air passes into the side ventilating-chamber and escapes through the grated opening above. At the bottom of this chamber is a space intended to receive any solid materials that may pass through the grate. The flap at the discharge end of the sewer compels the gases to escape by the opening above instead of traversing the sewer from a lower to a higher elevation. The charcoal is used in mass, and therefore interferes with ventilation. The position of the trays is also objectionable, since they have to be removed whenever the man-hole is used for examination of the sewer. The other plan adopted by Mr. Rawlinson, where the screen is placed vertically between the man-hole and ventilating shaft, is preferable on this account.

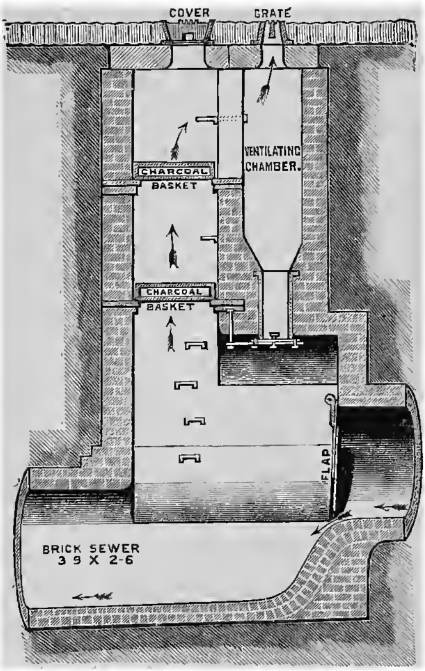

FIG. 34.—Manhole, tumbling-bay, and double ventilating arrangement.

Other forms of charcoal sewer-ventilators have been devised, but none of them are free from the objections already alluded to. The form introduced by Mr. Latham, in 1869, combines the greatest number of advantages, and has, therefore, been very generally adopted by engineers, where it has been deemed necessary to use some form of charcoal ventilator. Reference to Figs. 35 and 36 will explain the action of this ventilator. The frame, *a*, receives the cover, *C*, and to its under-surface are attached the dirt-box, *d*, and charcoal ventilator. The centre cover, *C*, (filled in with wood, concrete, or asphalt) protects the charcoal from rain, or from water used for sprinkling the streets. Around this solid cover, *C*, is the open grating, *g*, by which air escapes from the sewer, or is drawn into it. The dirt-box, *d*, hangs under this grating; *S* is an open spiral trough, used for conveying the overflow-water from the dirt-box to the sewer. The spiral tray, *t*, represented by Fig. 36, is made of galvanized iron, in order to protect it from the action of the sewer-gases. After being filled with charcoal, the tray is screwed into the ventilator over the spiral trough, *S*, by means of the handle *h*. To use Mr. Latham's words, "The advantages of this ventilator are: 1st. That should the charcoal concrete in the tray, or if its pores are stopped with dust, no impediment is offered to ventilation, as there exists a free communication between the sewer and the external atmosphere. 2d. That the charcoal is completely protected from rain or water entering the ventilator or leaking through the joints of the cover, consequently it will retain its efficiency for a long period. 3d. That the passage provided for the overflow-water from the dirt-box is not dependent upon traps or any other uncertain device needing assistance to maintain it in perfect working order. 4th. The escaping vapors are all brought in contact with the charcoal, it being impossible for any to escape by the sides of the tray or in any other way."[1]

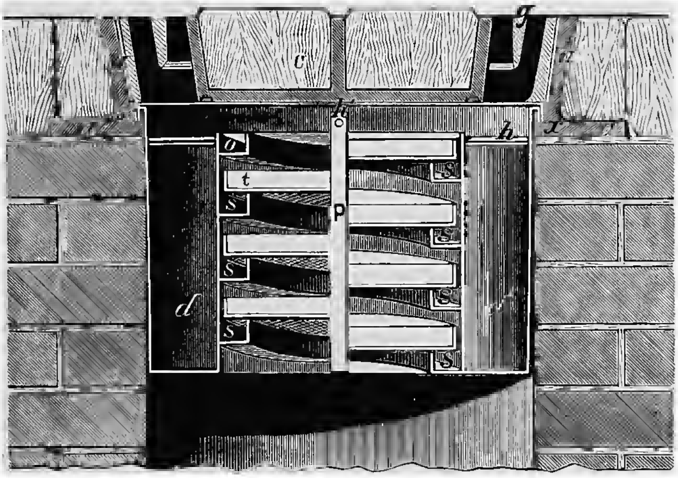

Fig. 35.—Latham's charcoal sewer-ventilator.

The charcoal used in this form of ventilator is broken to about the size of filberts. It is advantageous to remove it about once a month, and to prepare it for further use by reburning in iron retorts, atmospheric air being excluded during the process. The total cost of the management of these ventilators in Croydon, including reburning, labor, etc., amounted to one dollar and twenty-five cents per annum for each ventilator.

Notwithstanding the advantages claimed by Latham for this kind of ventilator, the verdict of the most experienced engineers is now pronounced against its general use. Charcoal is "so often an evil rather than a benefit, that, as a rule, it should be discarded from sewerage systems" (Denton). Any device which obstructs the free circulation of air into and out of the sewer is objectionable. The greatest possible *dilution* of the sewer-air is the object to be aimed at in sewer-ventilation, and this can be best attained by providing, as has been already recommended, a sufficient number of openings at man-holes and

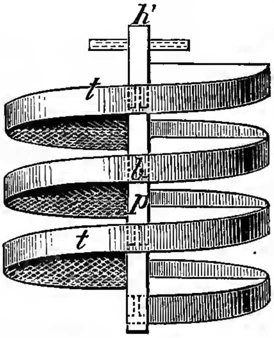

Fig. 36.—Spiral tray.

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[1] Op. cit., p. 44.

lamp-holes, and by means of shafts carried from the sewer up to the level of the street.

House-drainage.—No system of house-drainage can be said to be complete that does not insure the rapid and thorough removal of all liquid refuse, waste-water, and fæcal matter without leakage by the way, and, at the same time, prevent the entrance of air from the sewer or from the drain-pipes into the house. As a rule, these objects are very imperfectly attained, either on account of faulty construction of the drainage arrangements, or from defects in the plan of the works, or from their subsequent improper management. It is not intended, in this place, nor is it necessary, to give a detailed account of all the varied appliances which are in use. It will suffice if the correct principles be stated upon which these important sanitary works should be based, and the best means pointed out by which these principles are to be carried into effect, so that the evils which inevitably result from a bad system of house-drainage may be avoided.

The house-pipes which receive the waste matters from water-closets, sinks, baths, etc., and empty into the private sewer or drain-pipe which connects with the common sewer, are made of iron, lead, or earthenware. The drain-pipes are usually made of glazed stoneware or earthenware. Iron pipes are sometimes used, and, when well-made, and of proper thickness, and carefully laid, they form a very serviceable conduit. Brick drains and porous earthenware pipes are always to be discarded.

Glazed stoneware or earthenware pipes are to be preferred for house-drains. In laying these pipes, especial care must be taken to make the joints thoroughly watertight, so as to prevent the escape of the liquid sewage into the underlying soil, and the collection of sediment in the pipes, which will ultimately choke them. The pipes should be laid in well-puddled clay. In loose, dry soils a broad bed of concrete will give better results.

In new-made ground it will be necessary, in order to avoid disarrangement and leakage of the pipes, to use piles in addition to the concrete; or support and stability may be secured by laying the drains upon boards sustained by piers of brickwork.

In very wet soil, the use of the compound drain-pipe and subsoil-pipe, shown at Fig. 10, will answer every purpose. Joints packed with tarred gasket, and then bedded in cement or concrete, are not only rendered watertight, but they prevent the penetration of the roots of trees and shrubs, which, if admitted, speedily choke the pipes and make them useless. Coating the joints with coal-tar, or packing them with asphalt, is also said to prevent the entrance of roots of trees.

Drain-pipes should not be laid inside the house. If this cannot be avoided, every precaution must be adopted to prevent any escape of sewer-air or liquid filth from the drain. It is recommended that the pipes be placed in a position easily accessible. They should be embedded in concrete, and provided with means of inspection without disturbing the invert. "Access-pipes" are now made for this very purpose, and, when carefully laid and jointed, allow no escape of their contents. Two kinds of access-pipes are shown at Figs. 20 and 21. By inserting one of these pipes at intervals of—say one to every ten ordinary pipes, the whole drain is brought under control, and may be cleaned by means of flexible bamboo or jointed rods, without disturbing the bed of the drain. Parkes advises, in all cases where the drain-pipe must pass under the house, that it is much better to place it above the basement floor than beneath it, and to have it exposed throughout its course.

Where the drain-pipes pass through or under the foundation walls, it is recommended always to turn a relieving arch over them, otherwise the weight of the superstructure may cause them to crack or to open at the joints and leak, with evil consequences, or the pipes may be crushed by a weight which they are not fitted to sustain.

The course of the drain-pipe connecting with the sewer should be straight, if it is possible to make it so. When such a course cannot be obtained, and it is necessary to change the direction, curved pipes should be used, such as are sketched at Figs. 37 and 38.

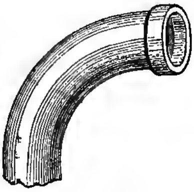
FIG. 37.—Quarter bend.

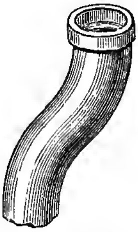
FIG. 38.—Offset.

The union of one drain-pipe with another, or with the common sewer, should be effected by a curved junction, adjusted so as to deliver the sewage obliquely in the direction of the flow of the main current. Pipes are made with these junctures cast upon them. There are a great many varieties of shapes, but only those forms are represented in Figs. 39 to 45 inclusive, which are best adapted for facilitating the flow of sewage from one pipe to another without danger of causing sedimentary deposits. These special pipes are made with single and double-curved or oblique junctions, which are variously inclined toward the line of the

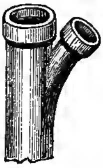
FIG. 39.

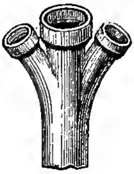
FIG. 40.

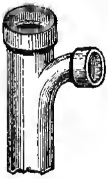
FIG. 41.

Curved junctions.

pipe, to suit the angle at which one drain-pipe may be joined to another. Square or right-angled junctions are also manufactured, but they should never be used, as they cause deposits to form which may ultimately block up the pipe altogether. Fig. 74 illustrates the manner in which this effect is produced. The taper-pipe, shown in Fig. 46, is often used when it is desired to reduce the calibre of a drain-pipe. It is usual to give the drain-pipe an extra dip whenever a bend or a junction occurs in its course.

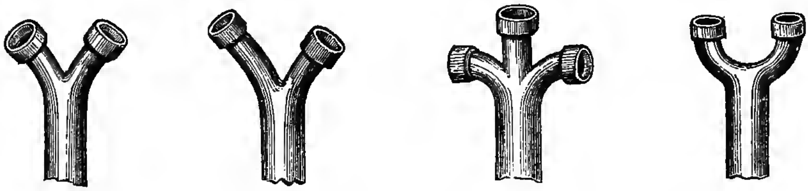

Fig. 42. Fig. 43. Fig. 44. Fig. 45.

Double-curved junctions.

Fig. 46.—Taper-pipe.

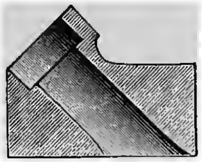

Fig. 47.—Junction-block.

The communication of the drain-pipe with the common sewer should be just within the ordinary water-line, and the junction should be made by the use of a "junction-block," a section of which is shown in Fig. 47. These blocks are made of stoneware or fire-clay, and are placed in the walls of the sewer when first constructed, or they may be inserted afterward as occasion may require. The branch enters the sewer in an oblique direction and forms a most excellent means of making a tight connection with the sewer. Ordinarily, the junctures are made in the rudest possible manner, and, even when the work is carefully executed, more or less injury is done to the pipe or sewer, which may be only temporarily remedied by the use of cement. Some writers recommend flap-valves to be placed at the termination of the house-drain in the sewer to exclude sewer-air and prevent the back flow of sewage. Experience has proved the recommendation to be unwise, as these valves are liable to get out of order, when they defeat the object for which they are applied, and, moreover, they tend to impede the current of sewage, especially when they are out of repair. Other devices are in use which more safely and successfully attain the object sought to be accomplished by these flap-trap arrangements, the mechanism of which will be hereafter explained.

It is of great importance that the drain-pipe should have a sufficient inclination to secure a free and uninterrupted flow of water from the house-pipes to the sewer. Denton says the velocity should not be less than three feet nor more than ten feet per second. If less than three feet per second, the greatest care should be exercised in selecting pipes with a perfectly smooth interior surface, and even then it will be necessary to resort to frequent flushings to keep them free from obstructions. According to Latham's Tables for determining the proper inclination of drain-pipes for different velocities, the rate of inclination for a velocity of three feet per second, for a four-inch pipe should be 1 in 92; for a six-inch pipe, 1 in 137; and for an eight-inch pipe, 1 in 183. This calculation is based on the assumption that the pipes are running full or half full. But as it is seldom the case that the pipes carry to the extent of their capacity or even half of it, a much greater fall will be required than that indicated by the table. Mr. Eassie recommends that, as a general rule, a fall of 2¾ inches or 3 inches to every 10 feet be allowed, which is about 1 in 40.

It is important to adjust the size of the drain-pipe to the greatest volume of sewage required to be conveyed by it. As a rule, drain-pipes of too great calibre are used. A four-inch pipe will be ample for the ordinary drainage of a house. If water-closets are in use, a pipe six inches in diameter will be required; in fact, a pipe of this size will be sufficiently capacious for all except the very largest establishments, for which a nine-inch pipe had better be provided. When the drain-pipes are too large they fail to be self-cleansing, unless the inclination be made unusually great.

The proper management of house-drains involves the use of appliances for the periodical discharge of a large volume of water through the entire length of the pipe, so as to remove all obstructions and cleanse the surface of the pipe above the usual water line, which is liable to be covered with a fungoid growth. In some systems, the water-closet is provided with a special arrangement by which, on each occasion of the use of the closet, a considerable quantity of water passes into the basin and thence into the pipe. Another plan is to collect the sink-water in trap-tanks, and then to suddenly discharge it into the drain-pipe. This object may be automatically effected by the use of Field's flush tank, into which a certain amount of rain-water may also be allowed to flow. The best plan is to provide tanks above ground or underground for the collection of rain-water; or these reservoirs may be filled from the ordinary water-supply, and at intervals of about once a month their contents should be discharged through a free opening into the drain-pipes, so as to thoroughly *scour* them from one end to the other. It is advisable to have these opening outside the dwelling, if possible, as, during the operation, the sewer-air, displaced by the rush of water, will escape into the house unless this precaution is taken. The traps are very liable to be emptied by the flushing, and it is therefore wise to pass water into them immediately after the operation.

It is very important that a correct plan of the underground drainage arrangements of every house should be provided, showing the size and course of the pipes, the position of the bends, junctions, traps, and access-pipes, the depth of the pipes from the surface, and the nature of the soil. Any alterations subsequently made should be carefully noted upon it. The landlord should be required to furnish a drainage-plan to the tenant making a lease; and such a plan, properly certified, should accompany the deed of every property.

Ventilation and trapping of drain-pipes.—Two important principles are to be insisted upon in house-drainage. The first is the maintenance of a constant and ample supply of fresh air throughout the entire length of the main drain, and the soil-pipe connected with it; and the other is the exclusion of sewer-air by means of some kind of trap arrangement placed in the main house-drain just outside the building. The former object may be accomplished by carrying the soil-pipe, of full diameter, to some distance above the top of the house, and providing it with a cowl to improve the draught, fresh air being supplied at the lowest part of the drain-pipe, somewhere between the outside trap and the entrance of the soil-pipe, by means of a small air-pipe or other opening. In cold climates, where an opening between the drain-pipe and the outer air might be dangerous on account of frost, the pipe admitting fresh air may be carried underground for some distance to temper the air before it enters the drain.

A common plan of arranging house-drains is to carry the pipes directly into the sewer, without a break in the continuity, and without providing a means of ventilation, dependence being placed upon the small traps in the house to exclude sewer-gas. This is a most delusive practice, and cannot be too severely condemned. The sewer-gas, when compressed from any cause, is certain to force the small water-seals, and diffuse itself throughout the house.

An efficient trap should be placed in the main drain just outside of the house, to prevent the entrance of sewer-air; and the soil-pipe should be continued to the top of the house, as suggested above. But this plan is not complete; for it does not insure a free circulation of atmospheric air through the house-drain. Lest the sewer-air should be forced through the trap, or be absorbed by the water forming the seal, and emitted on the side toward the house, an opening should be made in the drain-pipe between the trap and the house, communicating with the outside air, and protected above the surface of the ground by a grating, so as to form an air disconnection between the house-pipe and the drain leading into the sewer. This will also afford a free circulation of air through the house-drain and soil-pipe; and any sewer-air that may pass the trap, should it not escape through the grating, will be so thoroughly diluted as to be innoxious. The Molesworth trap, Fig. 48, illustrates this principle. By this arrangement an excellent provision is made for the discharge of rain-water, and waste-water from sinks, baths, etc. The smaller waste-pipes —which should be trapped inside the dwelling to prevent the effluvia from the trap being drawn into the house—and the rain-water pipes may be discharged upon or near the grated opening, G; while the foul matters from the water-closets are carried off by the pipe D. The pipe D is continued above the top of the house. Any effluvia arising from the trap, or any sewer-air that may be forced through the water-seal, will either be discharged through the grating at G, or be diluted, and carried upward, and discharged into the atmosphere above the house with the body of air entering at the grating G.

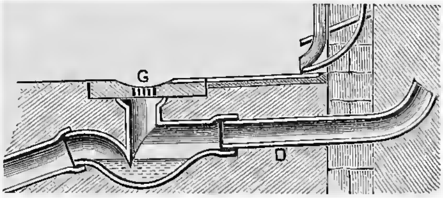

Fig. 48.—Molesworth's trap; D, house-pipe or house-drain; G, grating to receive water from rain-pipe and small waste-pipes, and to afford ventilation.

Another arrangement, suggested by Professor Reynolds, deserves mention on account of its simplicity and efficiency. It assumes that all the drains in the house flow into one pipe, which should be the only connection between the house and the sewer, and provides for the effectual trapping of this pipe. This is a principle which should always be observed. The device is illustrated by Figs. 49 and 50, and is described as follows: "A man-hole or shaft is sunk from the surface to the pipe, the floor of the man-hole being about two feet above the bottom of the drain. Across this floor there is an open trough which takes the place of the pipe; this is about two feet deep, and of the same width as the pipe. The ends of the pipe which are connected with the trough are (as shown in the diagram) so depressed that the water stands in the trough about half an inch above the orifice on the sewer side, and an inch above the mouth on the house side. In this way a trap is formed which effectually closes both the house and the sewer from the man-hole, and doubly closes the house from the sewer. And if care is taken to arrange the orifices of the pipes in the man-hole as recommended, it will not be possible for the water to be sucked out of the trap, should the pipe run full. The man-hole affords a ready means of examining or cleansing out the trap, but in order to prevent a scum from forming on the surface of the water in the trough, the pipe from a roof-spout may be arranged

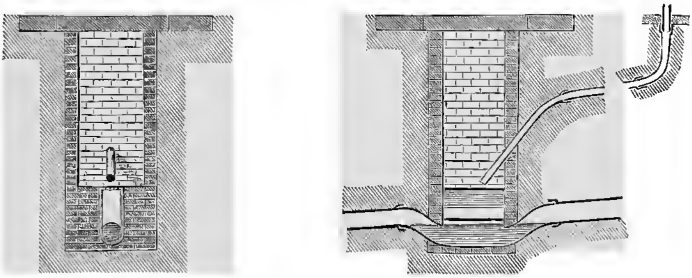

Fig. 49. Fig. 50.

Reynolds's man-hole and trough, and rain-spout opening over trough.

so as to discharge itself on to the top of the trough, as shown in the diagram."[1]

The same principle may be carried out in a simpler manner by using a special earthenware or iron trap, as represented at Fig. 51. A pipe is inserted in the centre of the syphon and carried straight up to the surface of the ground where it may be protected by a grating, or it may be continued to the top of the house, if desirable, but in no case should the rain-water pipe be utilized for this purpose, for when most needed for ventilation, viz.: at the time of a storm, it will be wholly employed in its own specific work. Between the water-seal and the grating at the surface there should be a side junction in one of the pipes near the top of the shaft for the discharge of rain-water or waste water from the house, similar to the arrangement shown in Figs. 49 and 50.

There are a great many similar arrangements for disconnecting drain-pipes outside the house, but the examples furnished, which are among the best, will answer to explain their construction and their uses.

The opening of the drain-pipe to the outer air, after the manner just alluded to, may possibly be the cause of a nuisance, especially if the opening be near a window. It may be desirable, therefore, to make use of some plan for disinfecting the air escaping from these openings. Various devices are in use for accomplishing this purpose. The accompanying diagram, Fig. 52, copied from Eassie,[2] illustrates a very simple device for deodorizing the unpleasant smells by providing a charcoal tray fitted in the ventilating-shaft above the surface of the ground. The effluvia from the drain, D, are intercepted at the mouth of the upright pipe, placed over the syphon trap, A, and are compelled to pass through the charcoal in the tray under the earthenware cap at B, before escaping into the outer air, and are thereby robbed of their offensiveness. Two other plans for ventilating drain-pipes are shown at Figs. 53 and 54. Charcoal is the deodorizing material used in both these contrivances. In the Brooks ventilator the charcoal is deposited in mass in the tray, T, placed upon the top of the ventilating-pipe. Any foul gas entering the upright shaft must pass through the porous charcoal before escaping into the open air. The tray is conveniently located, and can be removed with the greatest

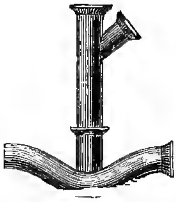

FIG. 51.—Simple ventilating trap.

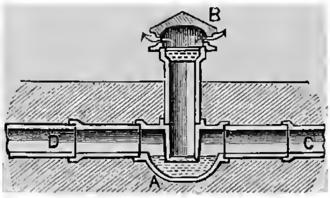

FIG. 52.—Deodorizing trap.

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[1] Reynolds: Sewer-Gas, etc., London, 1876, p. 12.

[2] Sanitary Arrangements for Dwellings, 1874, p. 38.

ease. This form of ventilator is much used in England. The arrangement represented by Fig. 54 is an invention of Mr. Latham. The principles of its construction and the advantages it possesses have already been explained in connection with sewer ventilation. This particular form is well adapted for the ventilation of sewers in courts, alleys, narrow streets, and confined places. The lid is kept perfectly tight by a sand-trap, or an india-rubber joint. The outlet of air from the sewer or drain, after it has passed the charcoal trays, is through the ventilating-pipe, which is carried above the top of the adjoining houses. If from any cause the charcoal is neglected, the sewer-air will pass through this pipe and be diffused in the atmosphere without causing any annoyance.

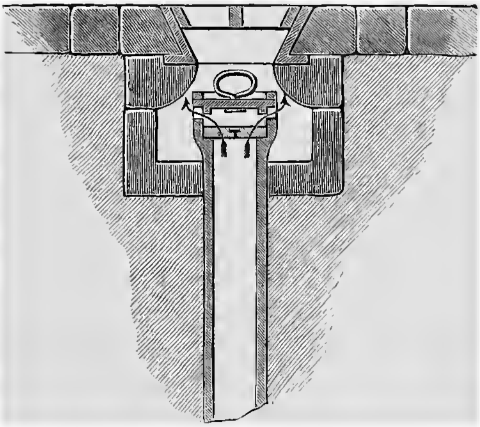

Fig. 53.—Brooks' drain-pipe ventilator.

If the ventilating-pipe is not required, a grated opening may be substituted for the solid lid. This particular form of ventilator is well adapted for use in drain-pipes of large public buildings, or, wherever, on account of the great length of the drain, foul gases are liable to form in large quantity. By all of these arrangements the rain-water is excluded, while all the gases rising from the drain are compelled to pass the barriers formed by charcoal.

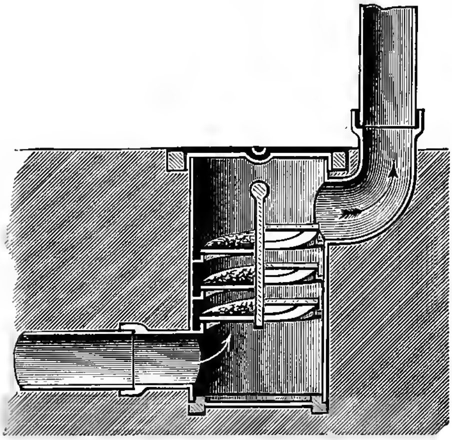

Fig. 54.—Latham's charcoal ventilator for confined places.

It is a common practice to ventilate drain-pipes by means of rain-water pipes. We have already shown why they cannot be depended upon to perform this service when most needed, that is, during storms. They do act at other times. The more efficient they are as ventilators, the more dangerous are they as disseminators of foul air, by reason of their openings being placed under the eaves of houses, frequently close to open windows. In certain cases they may be used without objection, but these cases should be well selected. Rain-water pipes are very frequently connected with drains to prevent the nuisance caused by the flow of water over the sidewalk, and the formation of ice in cold weather. Where this is the sole object, the practice may be allowed, provided, however, that the drains be thoroughly ventilated from some other source.

It has been recommended that house-drains be ventilated by means of chimney flues, but this plan should never be adopted. There is no certainty of a constant up-draught in the flue, and besides, bricks, of which the chimneys are constructed, being porous, will absorb the sewer-air, and in time become very offensive.

Eassie refers[1] to a system "in practice for ventilating the house-drains by leading a junction from the drain-pipe to the back of fire-grates or kitchen ranges, at which places a fire-brick chamber is formed, where the air can be rarified, and then taking a metal pipe from this chamber up to the house-top." He is opposed to this plan, since it encourages the practice of laying the house-drains under the dwelling. This objection is not a valid one, as the inlet pipe attached to the air-brick of the range can be made as tight as a gas-pipe, and may be made to connect with the common drain outside of the building without impairing its efficiency. There is often no other way of gaining access to the common sewer except by means of pipes laid under the dwelling. In cities this course for the drain is by far the most common one. Many houses have no rear outlet; others, more favorably situated in this respect, can make no use of the advantage on account of the absence of sewer facilities in the back street; then again, some of the finest residences have their bath-rooms and water closets in the centre of the house—a most pernicious practice—so that the drain-pipe must necessarily lie under a portion of the building. If the pipes are of the best material and the drains are constructed in the best manner, the danger from this source is reduced to a minimum. The evil, if it may be called such, exists; and as it is, in most cases, next to impossible to reconstruct the entire drainage arrangements, it is the duty of the sanitary engineer to devise some plan to avert the dangers of the system. A plan recently devised and patented by Mr. Rand, of Philadelphia, for ventilating house-drains in the manner above alluded to, will insure complete ventilation of the entire house-drainage system, provided all the other parts are properly co-adapted thereto.

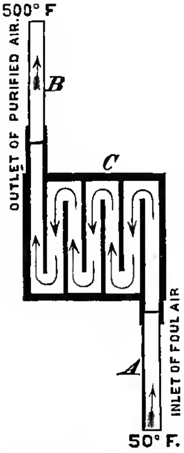

FIG. 55. — Section of air-chamber of Rand's house-drain ventilator.

Fig. 55 represents a section of a hollow cast-iron box intended to supply the place of an ordinary fire-brick in the kitchen-range or stove. It is made perfectly tight, and of sufficient thickness to resist the destructive effects of the fire to which it is directly exposed. At one end is

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[1] Op. cit., p. 33.

attached the inlet pipe *A*, and at the other, the outlet pipe, *B*. The box is provided with a number of partitions, *C*, which extend not quite across the air-chamber, the object being to create a sinuous course for the air, so as to expose it to as much heating surface as possible. The radiating surface is still further increased by means of metal points projecting from the sides of the air-chamber. With a slow fire the temperature of the air in the outlet-pipe, four feet distant from the range, has been found by actual test to reach 300° F.; with a hot fire the temperature has risen to 500° F. The air from the main drain-pipe enters by the pipe *A*, passes in the direction represented by the arrows, and is discharged by the pipe *B*. A coiled pipe is sometimes substituted for the air-box. A special heater may be constructed, if necessary.

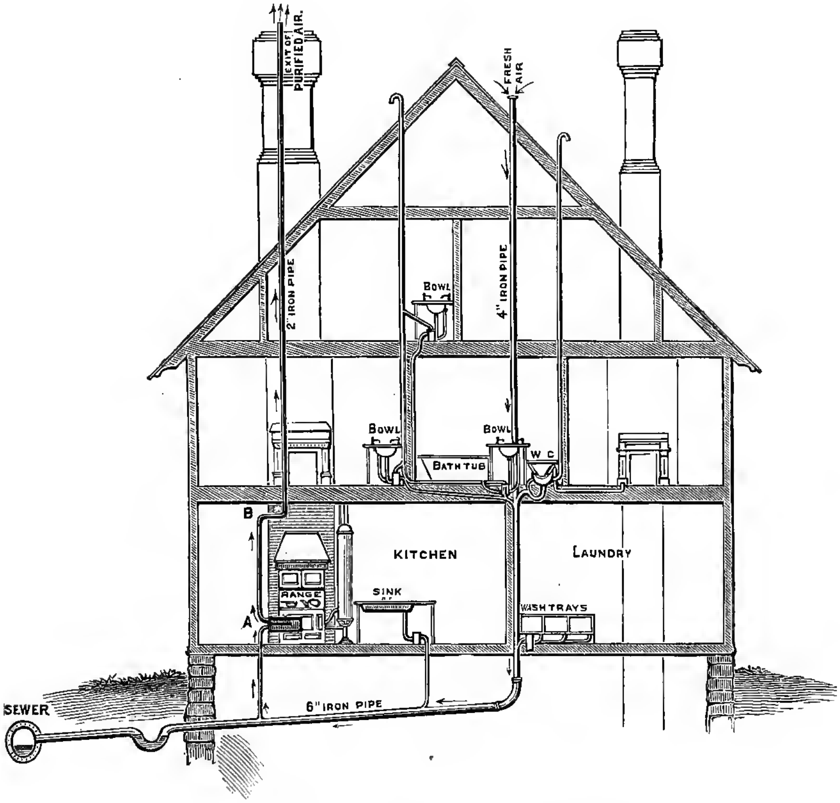

FIG. 56.—Rand's system of house-drain ventilation.

The plan of operation of this device is illustrated by the diagram, Fig. 56. The location of the bath-room and water-closet is such as is frequently adopted in city houses in this country. As will be seen by the diagram, all the pipes throughout the house are provided with traps. In addition to this safeguard, the precaution is taken to ventilate the principal traps themselves by means of special pipes running to the top of the house. The drain-pipe is trapped between the house and the sewer in the ordinary manner, and, at its other extremity, is connected by means of a curved bend with the soil-pipe, which is continued upward, at a diameter of not less than four inches, and opens into the air above the top of the house. Into the soil-pipe are emptied all the house-wastes except the sink-water, which passes directly into the drain-pipe. The main drain is tapped between the soil-pipe and the outside trap, as near to the latter as possible, by a two-inch wrought-iron pipe (provided with gas-tight joints), which is carried upward and joined to one end of the iron box in position in the range (Fig. 55, *A*). From the other end of this box (Fig. 55, *B*) a similar pipe is carried upward, through the chimney flue, to a point at or near its top.

By the suction power of the hot-air box, the air is forcibly drawn down the soil-pipe, through the drain-pipe and ventilating tube into the hot-air chamber, and is thence forced upwards through the wrought-iron ventilating tube, and discharged into the atmosphere above the house, thus constantly maintaining an active circulation. The tube AB, Fig. 56, is exposed for clearness of description; it should pass directly backward from the box into the kitchen flue.

It is claimed that the sewer-air is rendered innocuous by exposure to so high a degree of heat, and, therefore, when discharged, can cause no nuisance whatever. Should sewer-air escape through the trap placed outside the house, it will immediately be drawn into the ventilating tube and hot-air box, without gaining access to the soil-pipe with which the other house pipes communicate. This plan provides a constant supply of fresh air to all the house pipes and to the drain-pipe, relieves the traps from pressure from below, and provides for the destruction of the poisonous properties of the sewer-air.

Sink and waste-water pipes.—These pipes are usually made of lead, as it seems to be the most serviceable material. They are either connected with the soil-pipe, or made to discharge in the open air over a grating. The English authorities advise that they should never be connected directly with the drain-pipe, but should open outside the house over the grating of a trap or gully, through which the waste water passes into the trap, and thence, through the private drain, into the sewer. In this manner a complete air-disconnection is provided between the waste-pipes and the drain-pipe. This plan is well illustrated by Fig. 48. The outlet pipes under the sinks, wash-bowls, baths, etc., should always be trapped, to avoid any accidental influx of foul air. This method of air-disconnection should be applied wherever the climate will permit it. In many parts of this country its adoption would be attended with the greatest annoyance on account of the action of frost. It has, therefore, been usual, in places where the winters are severe, to connect the waste-water pipes with the soil-pipes, depending on water traps to exclude the sewer-air. When the lead waste-pipes enter the iron soil-pipes the greatest care should be taken to make the joints solid and secure; the use of glazier's putty is never admissible. There is also the most urgent necessity for efficient soil-pipe ventilation, which may be secured by some one of the plans already suggested.

Stationary wash-stands in sleeping apartments, when the outlet pipe is connected with the soil-pipe, cannot be too strongly condemned. If these conveniences are required, the waste-pipes should always be made to discharge in the open air and *not* into the soil-pipe or drain-pipe. They may be discharged near the grating of a flush-tank or gully connected with the drain-pipe.

Special provision is needed, in some cases, for the disposal of the waste water from the kitchen and scullery sinks. The grease discharged with the kitchen slops should be kept out of the drain-pipe, if possible, to prevent the serious inconvenience it occasions by adhering to the sides of the pipes and clogging the channel.

Ordinarily, the water-pipes from the kitchen and scullery are connected with the soil-pipe, or with the main drain, and the frequent discharge of hot water is relied upon to keep them clean, or to remove the grease when the pipes become choked up. Tanks may be used to intercept and collect grease and other substances from the water on its passage to the sewer. These tanks are made of brick, stoneware, or iron. Their proper location is outside the house. They are made to connect with the main drain by a trapped outlet, and are provided with ventilation by means of a pipe running up the exterior wall of the house, with an outlet above it. Mr. Philbrick describes[1] a simple form, Fig. 57, made of brick, laid in hydraulic cement, and plastered smooth on the inside. The inlet-pipe opens some distance from the water-line, so as to prevent the clogging of the pipe with grease. The outlet-pipe is curved, in order to facilitate the outflow of the liquid, and its mouth is placed about one foot below the water-line. A vent-pipe is arranged to pass up the side of the house, as

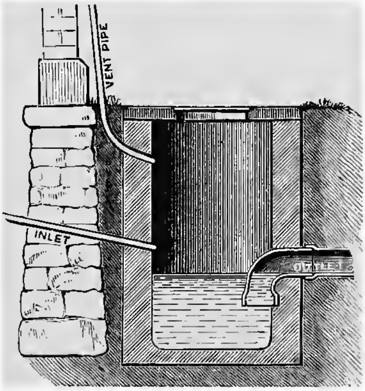

Fig. 57.—Cesspool or tank for grease.

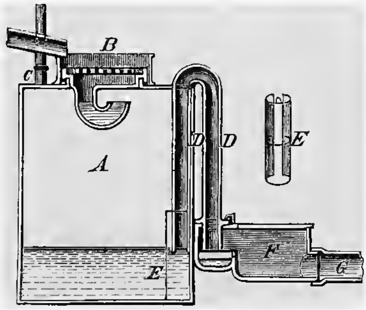

Fig. 58.—Field's flush-tank.

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[1] Seventh Report of State Board of Health of Massachusetts, 1876, p. 443.

before described. The grease collects on the surface of the water, and may be removed at the time of cleaning the tank.

Field's flush-tank is a very convenient form of intercepting tank. It is automatic in its action, and can be used for flushing the main drain-pipe. Mr. Denton gives the following description of the apparatus, which is here illustrated by Fig. 58. It "consists of a cylindrical, water-tight, iron or stoneware tank, *A*. This tank has a trapped inlet, *B* (which also forms a movable cover to give access to the interior of the tank), and a socket, *C*, for a ventilating pipe. The outlet consists of a syphon, *D*, so arranged that no discharge takes place till the tank is completely filled with liquid, when the syphon is brought into action, and the contents are immediately discharged. The inner end of the syphon is protected by a strainer, *E*, to hold back grease, etc.; and at the outer end enters a discharging trough, *F*, which is made to turn round so that its mouth may be directed as required to connect the tank with the line of outlet-pipes, *G*. This trough has a cover, which can be removed to give access for cleaning. In this contrivance the liquid refuse from the house-sinks is discharged on to the grating." The soil-pipes from water-closets should not be allowed to empty into these receptacles. Other kinds of tanks are in use; but the two varieties described above are sufficient to illustrate the principle upon which they are usually constructed. When exposed to severe frosts, these appliances are apt to have their functions interfered with; but the difficulty may be overcome, in most cases, by sinking the receptacles at a proper depth in the ground.

House-traps, sink-traps, etc.—There appears to be scarcely any limit to the variety of appliances used for the purpose of excluding from our houses the foul air generated in drain-pipes and sewers. Some of these have already been described.

The simplest form is the syphon-trap, illustrated by Fig. 59. If properly constructed, well laid, and frequently flushed out, it forms one of the best house drain-traps in use. To add to its efficiency, a junction should be provided, as shown at Fig. 60, so as to furnish a means for inspecting, cleaning, and ventilating the trap. A frequent cause of inefficiency of traps lies in their mode of construction. If the depression is too shallow, the level of the water in the curve will not be high enough to block the passage of air from the pipe below it. But even when the depression is sufficiently deep for this purpose, the trap may be emptied by the syphon action of the pipe beyond it, especially when the latter has a great and sudden fall. This may be remedied by making the pipe large

FIG. 59.—Common syphon-trap.

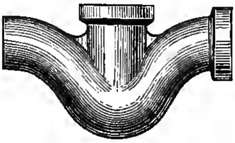

FIG. 60.—Inlet syphon-trap.

enough to prevent its running full, or by making the trap of a larger size than the pipe itself. A good trap may become useless by being improperly laid. Traps also become ineffective from want of proper management. As water is depended on to block the passage of the sewer-air, it is plain to see, that, when the flow is very infrequent, there is danger of the trap becoming unsealed by the evaporation of the water. Should the water not evaporate, between the intervals of the passage of sewage, sufficiently to unseal the trap, there is danger from another source. Unless frequently renewed, the water in the trap becomes impregnated with sewer effluvia, which are then discharged into the drain-pipe on the house side of the trap. This accident may be prevented by using a ventilating shaft, as shown in Fig. 60.

Traps sometimes fail in their object, on account of the pressure of the sewer-air—aided by the suction-power of the heated air of the house, forcing a passage through the water. Sometimes the water in the trap is displaced by these forces, though, according to Parkes and Burdon-Sanderson, this accident is rare if the trap be a good one. The remedy in these cases is thorough ventilation of the trap and house-drains.

Traps become useless from leakage or by the collection of sediment. A means of examination should always be provided, so that by frequent inspection these difficulties may be prevented or corrected.

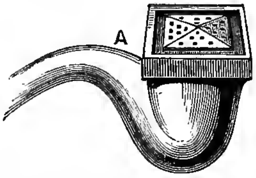

FIG. 61.—Earthenware syphon sink-trap.

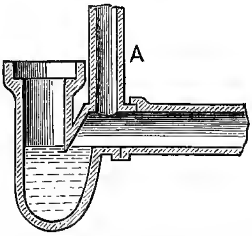

FIG. 62.—Ventilated syphon-trap.

A common form of sink-trap is shown at Fig. 61. It would be safer if provided with a ventilating tube connected at A, and leading to the exterior of the house, similar to that represented at A in Fig. 62. Bell-traps should not be used indoors, since the cover, with the inverted cup attached, is apt to be removed, in which case the obstruction to the passage of sewer-air into the room no longer exists. Another form of sink-trap, and a very good one, is that represented by Fig. 63. Should the cover be removed, the trap will still be sealed. These traps are sometimes arranged so that they can be locked, to prevent their improper use for the disposal of refuse, such as scraps of meat and the like. A form of S trap, shown at Fig. 64, is frequently used. It is made of iron, and has a means of access provided at the lowest part of the trap for the removal of obstructions. The inner surface should be well enamelled to prevent oxidation and the adhesion of waste matters.

Common earthenware S traps, used for closets, are illustrated by Figs. 65 and 66. They are found to give satisfaction, provided the soil-pipe is well ventilated; but they are not well adapted for the removal of obstructions, as they are not furnished with a means of access at the lower part of the curve. The iron traps are preferable on this account. Fig. 67 represents such a trap, which is provided with a movable cover made perfectly air-tight by means of a clamp and proper packing. This form of trap is also made with an outlet for lead-pipe connection, which is trapped by entering below the water-line. It may be used for the attachment of the waste-pipe from bath or wash-basin. Fig. 68 represents a trap for use in water-closets, which, Mr. Eassie says, "embodies all the requirements of modern times." He describes it as follows: "The pan of the closet, which is fitted into the socket, A, is ventilated by a pipe

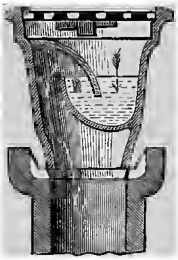

FIG. 63.—Trap and lock-grate.

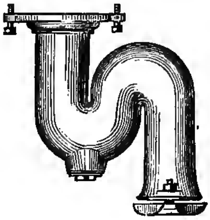

FIG. 64.—Iron sink-trap.

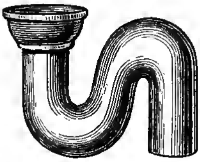

FIG. 65.—Earthenware closet-syphon.

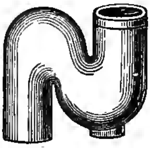

FIG. 66.—Earthenware closet-syphon of compact form.

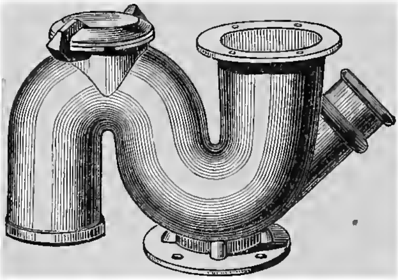

FIG. 67.—Iron closet syphon, with lead-pipe connection.

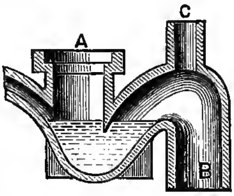

FIG. 68.—Improved water-closet trap. A, socket for closet-pan; B, outlet-pipe into drain; C, ventilating-pipe.

which joins the ventilating-pipe, C, and goes up to the roof. A two-inch supply-pipe from the cistern divides behind the closet-pan, and one moiety enters the pan above the opening, A, whilst the other enters the syphon-trap under the opening, A, through the inclined channel. These two streams of water act simultaneously when the water-valve is raised, and scour out both the pan and trap beneath, down the pipe, B, into the drain. Apart from the value of this improved syphon as a closet fitting, its use as a large ventilating-sink or other trap must be obvious."[1]

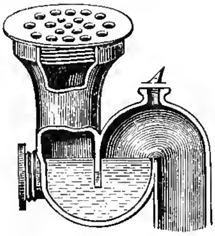

Fig. 69.—Sink trap.

There are various kinds of traps made for use in area-sinks, cellars, and yards. They embody in their construction the principles illustrated by the different forms already brought to notice. A simple and useful form is that presented at Fig. 69. If used in enclosed places, the pipe should be ventilated in the curve at *A*. The bell-trap, variously modified, is a form of trap in very general use for out-door purposes. If the cover be tightly fastened, and water be kept constantly in the receptacle, it will answer tolerably well the purposes of an ordinary trap. Fig. 71 represents a section of one of the simplest forms. The variety presented in section at Fig. 70 has the advantage of greater capacity for holding water, and therefore is less apt to become unsealed by evaporation.

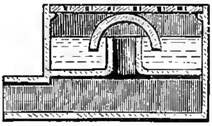

Fig. 70.—Section of bell-trap with square receiver.

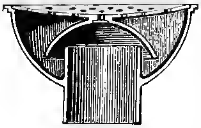

Fig. 71.—Section of common bell-trap.

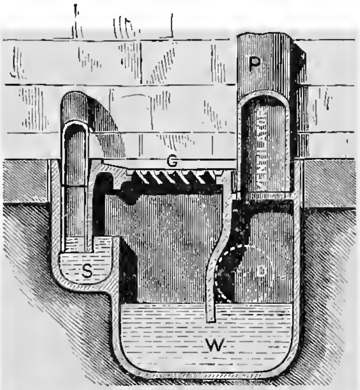

Fig. 72.—Mansergh's ventilating trap.

A good style of trap is that devised by Mr. Mansergh, and much used in England, which serves the double purpose of a yard gully and an outlet for the waste water from the house. It is made compactly in one piece of stoneware, and is provided with two water-seals, between which there is an open communication with the air by means of the grating G, Fig. 72. The waste-water pipe is sealed by the trap S, while the escape of sewer-

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[1] Op. cit., p. 48.

air at the grating is prevented by the body of water W. The outlet of the trap is at D, over which is a ventilating-pipe, P, running up above the top of the house. The waste-water pipe is well protected by two water-seals. Should the sewer-air pass the first seal, which is well protected by the ventilating-pipe so long as water remains in the trap, it will escape into the open air through the grating at G.

Before leaving the subject of traps we may make mention of a useful invention by Mr. Bower, in the form of a syphon-trap with a ball-valve combined, and intended for application to stationary wash-bowls and trays. By this device, exhibited at Fig. 73, the syphon action of the pipe is prevented. A represents the inlet-pipe, and B the outlet-pipe. The escape of gas from the pipe B is barred, first by the body of water in the receptacle or cup C, and, secondly, by the air-ball D, which presses firmly against the smooth concave surface at the end of the inlet-pipe A. So soon as the water ceases to flow down this pipe, the ball adjusts itself to the outlet of the pipe. Pressure of sewer-air upon the surface of the water in the trap causes the ball-valve to fit more tightly. The cup, C, is provided with a rubber gasket, so as to make an air-tight joint at F F. It is easily detached, in order to cleanse the trap. The cup is made of lead or glass. When not exposed to hard usage, the latter material is preferable, as it affords a ready means of inspection. Another useful trap for basins, sinks, and urinals is the one devised by Col. Waring, which is illustrated by Fig. 51, in chapter on Hospital Construction.

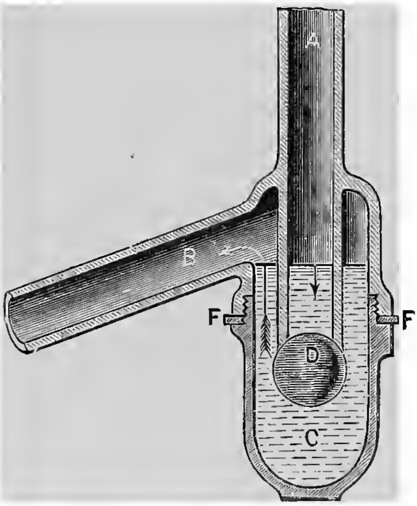

Fig. 73.—Bower's patent ball-and-water trap.

Water-closets.—The pipe connecting the water-closet with the drain-pipe is called the soil-pipe. In this country all the waste-water pipes from the upper part of the house are usually made to empty into it. Soil-pipes may be made of lead, iron, and zinc. The English give the preference to lead, but this material is more expensive than iron, and is apt to sag out of place, and it is in danger of being perforated by rats, or by nails carelessly driven. It is also liable to be perforated by the corrosive action of sewer-gas, as has been clearly demonstrated by Dr. Andrew Fergus.[1] When lead is used, the pipes should be drawn or cast, and not soldered together, as is sometimes the custom. In this country cast-iron pipes are considered to be superior to lead pipes. The chief objection

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[1] The Sewage Question: Edinburgh Med. Journal, 1878.

urged against them seems to be that they become coated from oxidation, and retain the fecal matter on account of their rough surface. Zinc and earthenware pipes are not often used for this purpose, nor are they desirable. Iron soil-pipes should always be of the very best quality, uniform in casting, and of smooth finish. An excellent article may now be had of domestic manufacture, which overcomes entirely the objection stated above. It is the *porcelain-lined* pipe, which, on account of cleanliness and durability, recommends itself to especial favor. The traps, bends, and other fittings are finished in the same manner.

The joints should all be well leaded and well calked, and the entire line of pipes should be firmly supported to prevent any strain upon the joints. Due allowance must be made for the expansion and contraction of the metal caused by changes of temperature. A diameter of four or five inches will be ample for ordinary purposes. At this same diameter the soil-pipe should be carried above the top of the house and left open at the extremity. A ventilating cowl is sometimes used to increase the outward flow of air.

It is important that the junction of the soil-pipe with the drain-pipe should be effected with a curved bend, such as is shown at Fig. 75, so as to retard as little as possible the flow of sewage from one pipe to the other. This is especially necessary when the junction is made with a pipe conveying sewage from another part of the premises. It is a serious fault to connect one pipe with another vertically, for this plan not only has the effect of impeding the flow of the waste matter, but it also tends to cause the formation of deposits, which, in time, may seriously interfere with the efficiency of the drainage. The effect of joining pipes at right angles is illustrated by Fig. 74. The obstructions usually form at the upper side of the connection.

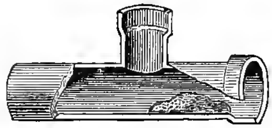

Fig. 74.—Faulty junction (Reynolds).

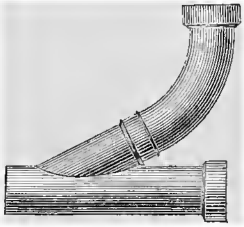

Fig. 75.—Correct plan of junction (Reynolds).

The soil-pipes should be placed outside the main building, if possible. Where the water-closets are placed in enclosures projecting from the side of the house, or in a tower constructed for the purpose—a plan to be recommended whenever practicable, this direction can easily be carried out. But it is too commonly the case that these conveniences are located within the main building. In such instances it is all the more necessary that the pipes be constructed of the best material, and set up in the most approved manner. Only such closets should be selected as are safe and sanitary in all respects.

The different kinds of water-closets which have been invented may be conveniently divided into two classes: those with valves and traps, and those with simple traps. Many of these devices are complicated and cumbrous, and are very liable to get out of repair. The simpler they are, the better, provided they fulfil the necessary sanitary requirements.

The requirements of a good water-closet are, that it shall be free from odor, simple in its construction, strong, and not liable to get out of repair; that it shall admit of being properly flushed, and be provided with the means of preventing the inflow of gases from the soil-pipe and sewer.

Any unpleasant odor arising from the closet indicates a gross defect in the apparatus. Ventilating the apartment may overcome the annoyance for the time being, but it only palliates the nuisance. The remedy should be radical. Sewer-air is not necessarily offensive, especially to those who spend most of their time indoors, and still it may be actively poisonous. The absence of a disagreeable odor is therefore not a reliable proof of the fitness of the appliance.

It should be made sufficiently strong to withstand ordinary usage, should be free from complicated arrangements, which are liable to get out of order, and should be perfectly smooth upon its interior surface, so as to be incapable of retaining any portion of the fecal matter. White glazed earthenware is the best material for the basin. The entire basin and trap are sometimes made of this substance in one piece, in the manner exemplified by the Jennings closet.

Provision should be made for efficient flushing and rapid and complete removal of the excreta. The water should be admitted with sufficient force to thoroughly cleanse the basin and sweep everything out of the syphon into the soil pipe. If the water be supplied from the house cistern, which is provided for storing water when the water-supply is intermittent, there is danger of foul air rising through the pipe which conveys the water to the closet when empty; it is therefore important that a separate cistern should be used for supplying the closet with water. By adopting this plan the contamination of the general water-supply of the house is prevented, and the waste of water is guarded against by appliances designed for this special purpose.

It might at first be supposed that where the water-supply is constant no danger of fouling the water in the service-pipe need be apprehended, by tapping it for a supply to the water-closet. And this is probably true where the Holly system is used, as the pressure of the water is so great that by tapping the service-pipe in the lower part of the house the flow to the upper part is not entirely interrupted. But in most of our cities, where the pressure of water in the mains and service-pipes depends upon the condition of the supply in the reservoirs, and where the distributing mains are often inadequate to the heavy demands made upon them at certain periods, the opening of a faucet in the basement, or lower part of the house, prevents the flow of water at a higher point. The consequence is, that, when the pipe connecting the service-pipe with the water-closet basin is opened, the water recedes and is followed by a rush of foul air, which will render the water subsequently drawn impure and unwholesome. The valves of the water-closet are frequently left open when the flow of water fails for a time, as when the demand is excessive, and the result is that the foul air from the "container" passes into the water-pipes, is absorbed by the moisture still adhering to their sides, and the impurities thus retained will be imparted to the water subsequently drawn from the pipe, and possibly used for drinking or culinary purposes. The remedy for this evil is to provide for the water-closet a separate pipe which shall not be drawn on for any other purpose, or to provide a special cistern from which the water used for flushing shall be taken.

The water is usually discharged into the basin by a flushing rim placed at the upper edge, or it may enter behind a fan arranged so as to spread the water over the entire surface. The outlet should be of good size, and so arranged that the volume of water, at the lifting of the valve, shall suddenly sweep over the sides of the basin and wash away through the trap all the excreta deposited in it. A good water-closet will prevent the escape of gases from the soil-pipe into the dwelling. This object is accomplished by a system of trapping and ventilation. A double trap and a double means of ventilation, if properly arranged, will protect the apartment against the entrance of sewer-air. The upper trap is formed by a body of water held in the basin by a pan or valve fitting closely to its bottom. The lower trap is usually of the form known as the syphon-trap, and is connected with the soil-pipe. Between the two is an air space, which should be ventilated by a pipe carried to the exterior of the building, or connected with the soil ventilating-pipe. The soil-pipe is ventilated by carrying it above the top of the house, as already pointed out. Should the main soil-pipe be tapped at a distance from the water-closet, it will be a safe expedient to connect the highest part of the branch soil-pipe, which will be the upper part of the curve, with the main ventilating-pipe, so as to insure more perfect ventilation of this branch.

The mode in which this combined system of trapping and ventilation acts is at once apparent. By ventilating the soil-pipe, pressure is relieved and the sewer-air is so diluted that there is but little danger of impurities being absorbed from it by the water in the trap. Should the sewer-air, from any cause, pass the first trap, it will find a channel of escape through the ventilating tube under the pan or valve. This ventilating tube also carries away any foul air that may be formed by deposits beneath the basin, which would otherwise be discharged into the room at the moment of opening the basin-valve or pan.

An additional plan for preventing the escape of effluvia into the room —which can hardly be necessary if the above suggestions are carefully put into practice—is the one described[1] by Mr. Philbrick. It consists of an annular ventilating tube, shown at Fig. 76, to be placed over the top

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[1] Seventh Annual Report of Massachusetts State Board of Health, p. 448.

edge of the basin and under the seat. It is provided with perforations around the inner edge of the ring for withdrawing the air that may escape when the contents of the basin are discharged into the pipe below. This tube is connected with an iron tube, three inches in diameter, which is carried into and up the kitchen flue. Before pulling up the handle connected with the pan or valve, the lid is shut down, so that any foul air escaping from beneath the basin is immediately sucked up by the superior draught of the tube, and discharged at the top of the house. If no chimney-flue is convenient, the tube may be carried directly through the roof, with some ventilating attachment at its top to increase the upward draught.

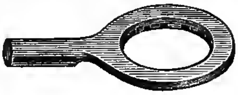

FIG. 76.—Annular ventilating tube over basin.

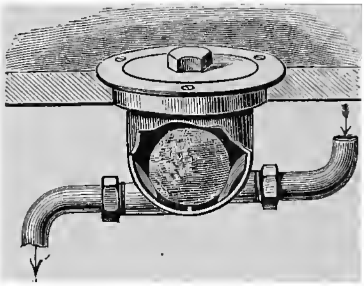

FIG. 77.—Wheeler's water-closet disinfector.

In some cases attempts have been made to disinfect water-closets by means of an apparatus connected with the supply-pipe of the closet, by which a certain portion of disinfectant fluid is discharged into the basin each time the closet is used. Various devices have been introduced to carry out this object. Of these, Wheeler's water-closet disinfector (Fig. 77) is perhaps one of the most efficient. It consists of a metallic cup-shaped reservoir, which is fitted in the wood-work of the closet at one side of the seat, and has the appearance, when in position, of the metallic cup for the handle of the valve-rod. The cap, when fitted, forms a water-tight joint. It is easily removed by a small wrench. The entrance of the supply pipe of the water-closet is on one side and the exit on the other. The lever controlling the flow of water is on the entrance side, so as to disconnect the service-pipe from the receiver, except at the time of use. The water passes through the receiver whenever the handle of the closet is raised, and is impregnated with the disinfectant—placed in the interior of the receiver—in the form of a solid saponaceous ball. The friction of the water flowing under pressure dissolves or disintegrates the material before it reaches the bowl. Carbolic acid and various other disinfectants are incorporated in saponaceous material, and compounded in such a manner as to dissolve at a known and even rate. When once attached the apparatus is automatic, and the only attention required is in replacing the compounds.

If a closet be properly constructed, disinfectants are rarely required.

In some cases, as when sickness of an infectious character prevails, the excreta should invariably be disinfected before being passed into the receptacle or sewer. This is usually effected by placing the disinfectant in the vessel before being used by the patient.

When water-closets are exposed to frost, the freezing of the water in the traps may be prevented by occasionally placing a little common salt in the traps.

Water-closets are constructed of enamelled iron, glazed earthenware, and china. Iron, when porcelain-lined, forms an excellent closet so long as the lining remains intact; but, should it get chipped or cracked, the water is brought in contact with the iron, and oxidation takes place, and sooner or later the destruction of the apparatus follows. Glazed earthenware is more durable, and, in many respects, the material to be preferred in the construction of these appliances.

Very few of the many kinds of water-closets which have been offered to the public from time to time, combine all the requirements necessary to fulfil the objects of this important sanitary contrivance. The popular demand is for a cheap article, and cheapness usually means inferiority. But even some of the more expensive appliances are not free from serious defects. Mr. Latham says that most of the water-closets used in the best houses in England are of the kind known as pan-closets. "They are expensive and cumbrous appliances, and cannot be introduced within a house without creating a nuisance." Mr. Denton says the pan-closets should always be looked upon with suspicion, and he holds the same opinion with regard to closets provided with what is known as the "D" trap. According to Mr. Bayles, the pan-closet is the kind usually selected in this country. He says, that "closets of this pattern are defective in principle and unsatisfactory in operation; and although they have been variously modified and improved during the past few years, it is doubtful if they are susceptible of such improvement as will wholly correct their inherent defects."[1] An ordinary pan-closet with a "D" trap is shown at Fig. 78. It consists of a basin, *B*, usually made of earthenware, a pan, *P*, which, when the handle, *H*, is raised, is tilted, and deposits its contents into the receiver, *R*, from which they fall down into the trap, *T*, and thence pass into the soil-pipe. When the pan (which, when closed, retains water to form a trap) is tilted backward by a sudden raising of the handle, the water and fæcal matter are thrown against the sides of the receiver, which soon become coated with a mass of foul matter. This undergoes decomposition, and the noisome gases generated,

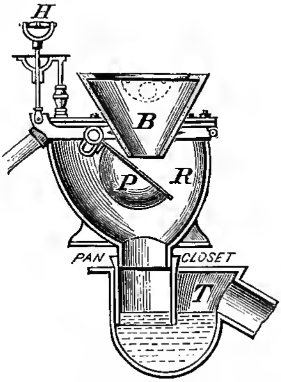

Fig. 78.—The ordinary pan-closet.

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[1] House-drainage and Water-service, 1879, p. 90.

collect in the receiver between the two traps, and are thence discharged into the apartment and through the house at every use of the closet. These gases, being almost constantly under increasing pressure in the confined space between the two traps, may escape through the upper water-seal, even when the pan is closed, in the manner already described.

Improvements have been made in this form of closet. One of these is the addition of an arrangement for flushing the receiver. Another is the ventilation of the receiver. And still another is the provision of a disinfecting apparatus, of the automatic kind, by which an even quantity of fluid is discharged into the basin at the closing of the pan. The annular ventilating-tube (Fig. 76) may also be used as a valuable adjunct to this apparatus. Although these improvements have made the pan-closet less objectionable, it is still defective in design, unnecessarily cumbrous, and far from being a perfect appliance.

The simple hopper closet, consisting of a basin and trap without either pan or valve or other complicated arrangements, if provided with an ample supply of water for flushing, and if well ventilated below the trap in the manner already explained, is one of the best of the cheaper kinds of water-closets. It is especially useful for outside closets or for apartments well separated from the main part of the dwelling. There is no chamber to conceal the filth, and if the water used for flushing is of sufficient volume and properly directed, the inside of the hopper and trap can be kept free at all times from foul matter. This apparatus is not liable to get out of order, and is easily kept clear, as any articles which get into the trap by accident, or are thrown into it, can be taken out by the hand or by a wire hook. The flow of water is generally regulated by a simple valve connected with the seat. This form of closet is much used in factories, prisons, hotels, and in poor neighborhoods. An excellent form of hopper closet is that shown at Fig. 79. It is made of stoneware, and can be easily kept clean.


Fig. 79.—Stoneware hopper closet and trap.

Of the better styles of water-closets, that known as the Jennings closet (Fig. 80) may be taken as an illustration. It consists of a basin and a syphon-trap in one piece of glazed earthenware. There is no pan or receiver, the fæcal matter being received at once by a large volume of water dammed up in the basin by a hollow plug, which acts as an overflow. To prevent any escape of gas through this hollow plug from the trap below, an inverted cup (not shown in the illustration) has recently been adjusted to the top of the opening, which effectually traps the air-hole.

When the handle, *H*, which lifts the valve, is raised, the whole volume of water is suddenly discharged through the water-trap below into the soil-pipe. The supply-valve can be adjusted to any pressure of water, and can receive it from the ordinary service-pipe or from a cistern. All back-flow of foul air is prevented by the peculiar construction of the valve. A socket, marked *V*, is provided for the reception of a ventilating-pipe. The branch, *W*, is properly located for the connection of a waste-pipe from a bath-tub or wash-basin. There are other excellent water-closets in the market, but it will suffice for our purpose to cite this one example to serve as an illustration of the principles upon which these important sanitary appliances should be constructed.

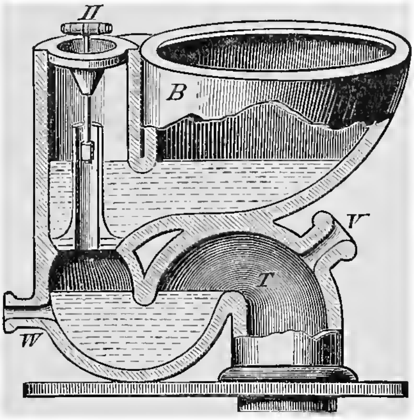

Fig. 80.—Jennings' all-earthen closet.

For large collections of people, or where a number of closets are necessary, water-troughs, or latrines, will be found serviceable. They are strong earthenware or cast-iron (porcelain-lined) receptacles, placed under a row of seats, with a slight inclination toward one end, at which a simple outlet with a valve is provided. The valve is lifted daily (or as often as may be required) by a person having special charge of the apparatus, and the entire receptacle is emptied at once. When the valve, or plug, is raised to empty the trough, each latrine is thoroughly washed in the same manner as a water-closet, by the automatic action of a valve controlling the water-supply. On closing the valve, the trough is immediately refilled with water to a proper depth. A receptacle should be

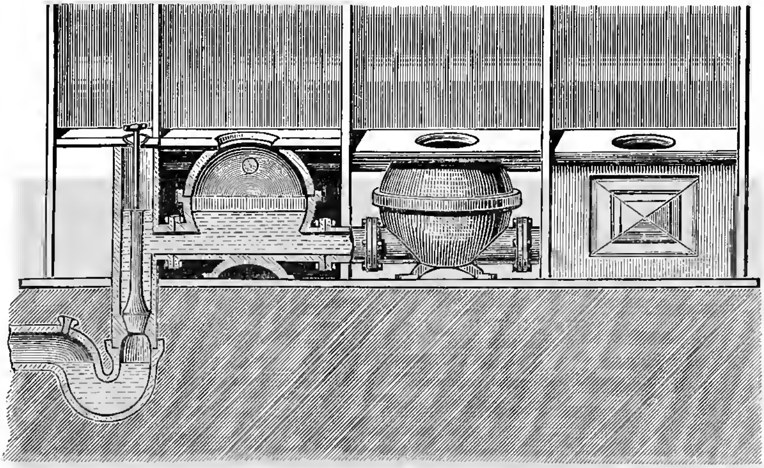

Fig. 81.—Jennings' latrines (modified).

provided to intercept any foreign substances that may be thrown into the trough and which might obstruct the discharge-pipe. The proper traps and ventilating-tubes should always be supplied. Fig. 81 represents Jennings' latrines modified, so as to have the valve arrangements in a separate apartment, and also by providing a socket for a ventilating-pipe. Another form of closet used in public places is the "tumbler water-closet." The apparatus is similar in construction to that described on a previous page, under the head of *Flushing of Sewers.*

Urinals.—Urinals are made of glazed earthenware or stoneware, or of porcelain-lined iron. The first-mentioned material is the best for the purpose. Some forms are made with slabs of slate. They require the greatest care to prevent them from becoming offensive. When located within doors, the waste-pipe should be well trapped close to the urinal itself, and provision should be made for ventilating the discharge-pipe by means of a tube carried outside the house, as already described. They are kept clean either by a constant supply of water so distributed as to sweep over every part of the inner surface of the receptacle, or the supply may be intermittent, the discharge taking place only by the turning of a valve, or by some arrangement actuated by the door of the apartment or by the weight of the person using the convenience.

Mr. Wheeler has constructed an appliance for disinfecting urinals, which has been tried with excellent results. The principle is similar to that described under the head of Water-closet Disinfection. The disinfecting agent—usually carbolic acid—is contained in the small chamber shown in Fig. 82, and, being in a solid saponaceous form, is gradually dissolved by the action of the water under pressure before it reaches the basin of the urinal. The water, in this manner, is constantly charged with a sufficient quantity of the agent to prevent decomposition, and the production of offensive effluvia. The occasional renewal of the compound, when dissolved, is all the care that is required.

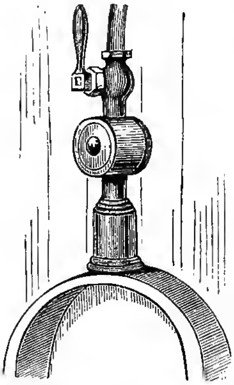

FIG. 82.—Urinal disinfector.

The examination of house-pipes and traps.—The regular and systematic inspection of the drainage arrangements of houses, although a matter of paramount importance in a sanitary point of view, is almost wholly ignored. House-drains, even when properly constructed according to the best possible system, require occasional examination. How much more necessary is it that house-fittings, as usually constructed, with a multitude of defects, should be periodically subjected to a thorough inspection, in order to detect and remedy serious faults, which may otherwise remain unsuspected until serious illness attracts attention to the probable cause of the trouble. Traps may become obstructed, openings designed for ventilation get clogged up, and joints may give way and allow the foul sewage matter to exude and pollute the ground under the dwelling. The pipes themselves frequently corrode by rust, or by the action of sewer-gas, as has been pointed out by Dr. Fergus, and allow the sewer-gas to escape. Various other defects may exist, unsuspected, unless some means of examination is resorted to at frequent intervals.

Because the house-drains have been well constructed, it is unwise to infer that they will always remain so. The fact that a drain is water-tight to-day is no guarantee that it will never leak. Considering the perishable nature of the materials used in its construction, the liability to disarrangement by accidental circumstances, as, for example, the settlement of a foundation-wall, and the frequency with which obstructions occur, either by the gradual deposit of matters suspended in the sewage, or by the surreptitious introduction of extraneous substances, it cannot be too strongly recommended that the drainage of every house be periodically examined, say at least once a year, under the direction of men skilled in sanitary engineering. The public authorities cannot assume this duty, nor intrude inside the house, unless a nuisance has already been created, and it is therefore necessary that the householder attend to it himself. But there is the common indifference that exists upon this subject, and the difficulty of securing the right sort of advice when attention has been aroused to its very great importance. Edinburgh has solved the problem by the organization of a sanitary protection association, under the leadership of Professor Fleeming Jenkin, and it would be well if the example were imitated in every town and city where the water-carriage system has been adopted.

The object of the association is to provide a thorough inspection, at least once a year, of all the drainage appliances of the house of every member, who, by the annual payment of a small fee, obtains the services of skilled workmen, acting under the advice of a leading engineer. These services may also be extended to the dwellings of the poor by giving to members the privilege of obtaining reports on such houses at a small rate. By special arrangement, schools, hospitals, hotels, and other public buildings may likewise share in these advantages. The association will confer direct benefits upon the individual members; but it will go further: "it will educate the community in sanitary matters, strengthen the hands of the public authorities, and indirectly exercise a most beneficial influence over the work executed on all new buildings."

When the drains are properly laid, so that every joint and bend can be readily exposed to view; when they are furnished with a proper outside trap provided with a grating, or with a well-hole for inspection; and if access pipes have been placed at convenient distances along the course of the drain—a complete examination of the entire house system can be made with very little difficulty and at trifling expense. But, on the other hand, when all the pipes and traps are entirely covered up, and there is an absence of the facilities for inspection, their direct examination will be difficult and necessarily costly. It is therefore necessary, in these cases, to resort to some other means of obtaining the desired information. This can be instituted without tearing up the ground, except when necessary for the introduction of an outside trap with ventilating grid, which will be required in conducting the experiments.

The plan to pursue in making the examination is thus described[1] by Mr. Jenkin: "1. Is the house drained? This will be tested by simply fastening up the water-closet handles for a few minutes, and watching the flow past the grid at the external trap. It is clear that no obstruction can exist on either side of the trap if this flow is seen to be unimpeded. 2. Is there any leakage from the sewer under the house into the basement? If so, of what magnitude? This will be tested by temporarily plugging up the drain at the trap, and filling the pipe or drain in the basement with water. If the water remains at a constant level, the drain is clearly water-tight; if not, the amount of the leakage can be measured by the rate at which the surface falls. No head of water should be put on the drain, or pipe, which is usually not designed to resist pressure; but all sewage-pipes passing under the basement of a house should be as tight as a bottle. It will, in this way, be quite easy to test the soundness of a drain, without uncovering it, and to repeat this experiment as often as may be desired. This experiment will also make sure that no old open ends are left connected with the main drain, as not unfrequently happens, with the result of allowing a part of the sewage to run out into the basement. 3. Are the pipes of a house air-tight? and are all openings trapped? This will be ascertained by making fumes of paraffine inside a closed vessel, over the open grid at the trap, and driving these fumes into the house system by a fan, but not so as to cause any internal pressure. When it has been ascertained that these fumes have reached the highest points in the pipes, each room in the house will be inspected, and any escape of paraffine into any room will certainly be smelt; the place of the escape will also be easily detected.[2] 4. Are the traps and pipes of a house properly ventilated? This will be ascertained by endeavoring to put the pipes under a slight pressure by pumping air into the pipes at the bottom. If no paraffine fumes are then forced into the house, it is clear that at least one part of the ventilating system is in order. In addition to this experiment, the test of passing smoke through ventilating openings will be made whenever this may seem desirable. 5. Is the drinking-water unpolluted? The cisterns will be examined, the position of the overflow-pipes recorded, and the action of the water-closets inspected."

2. *The Dry Systems.*

When sewers are properly constructed and managed, and there is no difficulty in dealing with the sewage at the outfall, and when the supply of water is abundant, the water-carriage system is undoubtedly the best plan for the removal of excreta. But in many places the use of sewers for excrement-removal is impracticable. There may be a want of

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[1] Edinburgh Med. Journal, April, 1878, p. 870.

[2] A similar test by means of oil of peppermint is in constant use by the sanitary inspectors of Boston.—(Dr. Draper.)

proper fall, or there may be a scarcity of water, or the climate may be so severe as to render all attempts at this mode of disposal a failure. In these cases, and for isolated houses, and villages, and small towns, there must needs be some other plan adopted for getting rid of the excreta without causing offence. In carrying out this object, some form of dry conservancy may be resorted to with advantage. Even where water is abundant, and the use of sewers is practicable, this plan is recommended by some authorities as preferable to the system by water-carriage.

The dry system consists in the admixture of dried earth, coal-ashes, or other dried refuse, with the excrement in sufficient quantities for absorbing and reducing it to an inodorous form, so as to prevent foul putrefaction and the consequent production of offensive gases. Certain conditions are to be observed in the application of this system. The material must be perfectly dry, and must be applied immediately, and in sufficient quantity to cover the excretions and remove all the fluidity of the material. All slops or sink-water or other fluids and solid substances must be carefully excluded, otherwise the sanitary objects of the plan will be defeated, and the agricultural value of the products impaired. Although with proper care the material will be completely deodorized, it is still very desirable that its removal be as frequent as possible. In rural districts this may be conveniently attended to; but in towns it is seldom that its removal takes place oftener than once a week, and frequently it is only once a month. The closets should be well constructed and frequently inspected, in order to see that their appliances are in proper working condition.

The location of the closet is also a matter of considerable importance. The same caution should be observed as has been suggested with regard to the position of water-closets, for, although the odor may be removed, there is no certainty that excrement retained in this manner about a dwelling may not, under certain circumstances, convey disease. The closets should be placed in an isolated part of the building, in an apartment projecting from the house, or, better yet, in a detached enclosure. Thorough ventilation should be maintained by the use of windows in the vestibule leading to the closets, or by a ventilating-flue, or by ventilating-glass in the windows, or by air-bricks near the ceiling of the room.

Ventilation of the receptacle may be effected by connecting it with the outside air by means of a tube. The receptacles should always be made of impervious material.

When powdered earth or well-screened ashes are used as the absorbent medium, the charged material may be dried and used a second time, or even oftener. It may be spread out under cover and exposed to the air, but the drying-shed should be removed from the house. In towns this is not advisable. And even in the country and in villages it is hardly necessary, as earth can be procured at trifling cost, and dried[1] and stored away without much labor. It is therefore safer to return it to the

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[1] Stoves are specially constructed for drying the earth.

land when once charged, and supply its place with fresh material. Earth should be well dried and thoroughly pulverized, and ashes should be well screened before being used, otherwise their absorbent power will be greatly reduced.

The dry method is an exceedingly convenient, economical, and efficient means of excrement removal where water-closets cannot be used. For country-houses, villages, small towns, and, under certain circumstances, for schools, prisons, and charitable institutions, this arrangement is certainly a most desirable one. It might be adopted with advantage in summer boarding-houses and hotels and at watering-places, in which, as a rule, the privy conveniences are extremely unsatisfactory, and frequently a source of discomfort and danger. No better substitute can be provided for the extremely filthy and dangerous arrangements which so commonly exist in this country, where water-closets are not in use, than some form of dry conservancy.

The systems under this head are: Moule's earth-closet system, the Goux system, and the ash-closet system.

Moule's earth-closet system.—This system derives its name from its originator, the Rev. Mr. Moule, who has advocated and brought into prominent notice the use of dried earth in closets on account of its powerful absorbing and deodorizing qualities.

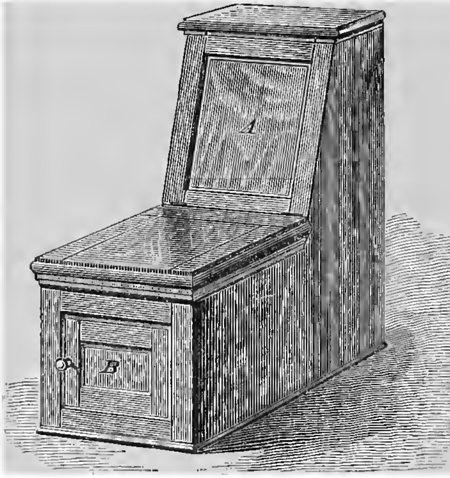

Fig. 83.—The earth-commode.

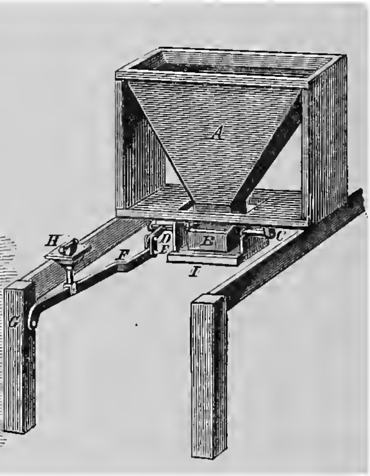

Fig. 84.—Mechanism of the earth-commode.

The original apparatus designed by Mr. Moule has been variously modified without interfering with its distinctive features, which are illustrated by Figs. 83 and 84. The closet consists of a wooden-box in two main compartments. The lower one, marked *B*, Fig. 83, contains a receptacle or pail for the sewage, and the upper one, *A*, the reservoir, or hopper, from which the dried earth is supplied in requisite quantity whenever the closet is used. The arrangement of the mechanism of this form of commode is shown in Fig. 84, and is thus described by Mr. Waring: "*A* is a swinging hopper capable of holding an ordinary coal-hod full of earth; *B* is the 'chucker,' which, on being tilted by lifting the handle, *H*, throws forward the proper quantity of earth into the movable hod standing under the seat. When the handle is released, the chucker drops back into the position shown in the cut, and is filled from the hopper, which enters its top, its mouth being at the same time closed by the shelf, *I*, suspended beneath it. The commode should be supplied with two hods, the one not in use being exposed to the air during the time that it is waiting. When fresh earth is needed for the hopper, it is carried to it in this dry hod, which, after being emptied, is substituted for the filled one under the seat."

This is the simple form of portable commode adapted for use in any room or closet. A fixed apparatus for regular use requires a modification of this plan, but the principle is the same. A reservoir for the dried earth may be fitted up, so that the supply need be renewed only at long intervals, and the inconvenience of frequent removal of the charged earth may be dispensed with, by carrying the soil-pipe down to a vault or portable receptacle beneath the lowest closet. The receptacle of each closet should be provided, at the bottom, with a sliding valve, which is opened by a handle when the holder is full, and its contents then pass through the pipe into the vault or other proper reservoir.

The principles to be observed in applying this form of the dry method are stated by Mr. Waring, as follows:

"1. The earth for use in closets must be dry; not necessarily dried by artificial heat, but made as dry as it can be by exposure to the air and by the exclusion of rain.

"2. It must contain enough alumina (clay), or organic matter, or oxide of iron, or be sufficiently powdery, to give it sufficient absorbing power.

"3. It must be sifted of its stones and coarser particles.

"4. The mechanical arrangement of the closet must be such that a sufficient quantity of earth will be, with certainty, deposited upon the fæces—enough to cover them and to absorb the urine of the single evacuation. And the accumulation under the seat must be occasionally raked down or levelled off in the vault, when an ordinary vault is used.

"5. When the vault or receptacle has become too full, its contents must be removed, and, before the supply is exhausted, the reservoir must be refilled.

"6. If the earth is to be again used, its organic matter must be destroyed by fermentation, and its moisture must be evaporated.

"7. In towns some system must be adopted for the supply of earth and removal of deposits, either by the public authorities or by private enterprise."

The advantages of the dry-earth system are summarized[1] by Dr. Buchanan, as follows:

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[1] Twelfth Annual Report of the Med. Officer of the Privy Council, 1869.

"1. The earth-closet, intelligently managed, furnishes a means of disposing of excrement without nuisance, and apparently without detriment to health.

"2. In communities the earth-closet system requires to be managed by the authority of the place, and will pay at least the expenses of its management.

"3. In the poorer classes of houses, where supervision of any closet arrangements is indispensable, the adoption of the earth system offers special advantages.

"4. The earth system of excrement-removal does not supersede the necessity for an independent means of removing slops, rain-water, and soil-water.

"5. The limits of application of the earth system in the future cannot be stated. In existing towns, favorably arranged for access to the closets, the system may be at once applied to populations of 10,000 persons.

"6. As compared with the water-closet, the earth system has these advantages: It is cheaper in the original cost; it requires less repair; it is not injured by frost; it is not damaged by improper substances driven down it; and it very greatly reduces the quantity of water required by each household."

The disadvantages of the system are—the trouble and expense of collecting, artificially drying, and storing the earth, especially in crowded localities ; the annoyance and expense of frequent removal of the soil, which has only trifling commercial value; the discomfort sometimes occasioned by the earth when in a very dry and powdery state; the constant care required, especially among the improvident classes, to prevent slops, sink-water, and other liquids being added, by which the object of the system would be defeated, and a nuisance created; and the necessity of supplementing this system with an additional provision for the removal of liquid refuse matters.

These difficulties would be greatly aggravated if the plan were applied to a large town of many thousands of inhabitants; indeed, it is tolerably certain that the use of the dry-earth system, or any of the dry methods, even as a substitute for the offensive privy nuisances which usually exist on premises unprovided with water-closets, however satisfactory for country houses, public institutions, and villages, is entirely impracticable for densely populated places.

Attempts have been made to obviate some of the difficulties mentioned above, by modifying the construction of the closet so as to separate the urine from the solid portions of the excreta, and allow the former to pass away by a separate channel. In one form the house-water can be carried off in the same channel with the urine. In another plan, the urine passes into some absorbent substance in the front of the receptacle, which is separated from the fæcal matter by means of a partition; the solids are therefore kept perfectly dry. By some these modifications are considered an improvement, but wherein it consists it is difficult to perceive, since they really unnecessarily complicate the apparatus and render it more liable to get out of order.

Charcoal is used in the same manner as the dried earth. It is a better disinfectant, but its use is more expensive, although a smaller quantity is required. Peat-charcoal is cheaper than animal charcoal, and may be used in its place. Mr. Stanford proposes to obviate the difficulty of price by obtaining charcoal from seaweed. It is a cheap article and very useful as a deodorant. After being once charged with the excreta it may be again used after being recarbonized in a retort prepared for the purpose, the products of distillation being sufficient to pay for the expense of reburning the mixture. Various kinds of deodorizing powders have been substituted for dry earth and charcoal, such as carbolic acid powders, Bond's terebene powders, cupralum, etc., but though these substances are efficacious, the plan is objectionable on account of the expense. The use of sawdust mixed with carbolic acid or sulphuric acid, or with chloralum powder has likewise been suggested, and tried on a small scale.

The Goux system.—This system consists in collecting the excreta in pails or receptacles lined with some dry absorbent substance, to which a deodorant is usually added.

" A tapering tub or container is provided, say 16½ inches high, and 20 inches at its greatest diameter. Upon the bottom of the tub is placed 3 or 4 inches of refuse, such as new stable-litter, loft sweepings, stack bottoms, ferns, shavings, sawdust, shoddy, flax dressings, spent tan, or hops, or the various waste materials to be found in the town or country; this is mixed with a little soot, charcoal, gypsum, or other deodorizer, for the purpose of packing or lining the tub. A mould of the same shape as the tub, but six inches less than the internal diameter, is placed upon the four inches of absorbent material referred to, and the space between the mould and the tub is packed with the same kind of refuse. One boy can pack eighty tubs in an hour, and this is all the manipulation required, excepting placing and removing the tubs at stated times. The absorbent material having been only moderately pressed down, the mould is withdrawn, and there remains a cavity into which the dejections fall, the liquid parts of which are taken up by the absorbents, and retained by them, so as to check fermentation."[1]

This system has been adopted at Halifax, and is said to work very satisfactorily. It is certainly an immense improvement upon the ordinary privy systems, and far superior to many of the plans now in use for disposing of excreta by means of pails.

The sanitary advantages of this system depend upon the careful preparation of the tubs, the exclusion of all extraneous matter, chamber-slops, and the like, and the careful supervision of the system by the authorities, so that the pails shall be prepared in a suitable manner, and carefully removed at the proper time, without causing any nuisance at the place or during the transportation of the material.

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[1] Bailey Denton: San. Engineering, p. 221.

The ash-closet system.—The ash-closet system has been introduced in several large towns in England, where it was desired to supplant cesspools and privies, and the results have been very beneficial. Reference has already been made to the use of screened ashes as a substitute for dry earth in the ordinary commode. The method under consideration refers particularly to the incorporation of ashes with excrement in pails, or small vaults, easily accessible for the removal of their contents.

The pails used at Manchester and Salford are made of galvanized iron, fifteen inches high, eighteen inches in diameter, and of a capacity of ten gallons. In both places cinder-sifters connected with the closets have been introduced, and appear to act very well. It has been suggested, by way of improvement, to make use of strong, wooden pails instead of the iron receivers, and to place the tubs on a level with the ground, instead of locating them in pits, in order to facilitate the removal of the material, and to secure greater cleanliness. The system provides for the frequent removal of the pail, in some cases as often as once a week. Mr. Radcliffe has made a careful examination of the system as applied at Manchester, and reports upon it as follows: "In the series of inspections I have made with reference to the working of this new system, I had occasion first to observe the contrast as to nuisance between the dry-ash closet and the old midden closet. In several streets where the process of reconstruction had been only partially completed, it was possible to compare the old and new privy arrangements in contiguous premises. It was the contrast between open, big, uncleanable cavities, containing a greater or less amount of decomposing fæcal matter, and emitting a horrible, penetrating odor, and small receptacles, emitting hardly any appreciable smell, even with the nose above the privy-seat, and admitting of thorough cleansing. Most significant testimony was given to the benefit of the change by some householders. Many houses in Manchester are built in parallel rows, a back passage running between the rows, and each house having a small yard in the rear, in which the privy is placed. Since the reconstruction of the privies, 'it has been possible to open the back windows of the houses.' The change, moreover, has affected beneficially the value of cottage property; and tenants are quite willing to give threepence more rent weekly, since the reconstruction of the privies, for the gain in decency and comfort. Soakage of excremental matter into the soil, and its passage into and accumulation in drains, is, of course, obviated by the reconstruction; and the smaller space occupied by the new closet is not an unimportant matter. The removal of the excrement-pail is, with the most ordinary care, free from offensiveness; and if commonly conducted, as I saw the operation, it may well be executed during the day-time, and the abomination of night-scavenging done away with. The use of the cinder-sifters has been adopted by householders with a readiness which proves how accurate the corporation was in depending upon their coöperation in the working of the scheme. The high price of coal during the last two years has contributed to this good result, from the value of the cinders in economizing its use. It is found, also, that a class of the population, commonly believed to be unmanageable in regard to any niceties of arrangement for excrement disposal, have rapidly appreciated the advantages of the new closet, and taken to the use of the cinder-sifter. In other words, it has been found that habits of decency and order in the particular matters referred to have been largely developed with the opportunities for such decency and order. Among the lowest class, occupying sublet houses, and having privies used by families in common, it will, however, probably be found necessary to adopt some special supervision, and to remove the excrement and dry house-refuse daily."

Another form of ash-closet consists of a small water-tight pit to receive the excrement and ashes. It is best illustrated by the arrangement adopted by the town of Hull. Instead of the movable receptacle, a shallow vault is used for retaining the excrement. It is built of bricks in cement, and is intended to be thoroughly water-tight. In front of the seat there is a movable board, to afford access to the pit. Ashes and dry refuse of the house are thrown down through the hole in the privy-seat. Rain-water and slops are intended to be excluded. The ashes absorb the moisture, and render the mixture sufficiently dry to be removed by a spade. The removal of the material takes place about once a week, and the carts used for the purpose are required to be water-tight and properly covered. The pit consists of nothing but the space between the seat and the flag or brick floor, which latter slopes a little from the front toward the back, where it is slightly below the ground-level. A separate closet is provided for each family; otherwise, in practice, it is found impossible to have the proper care taken of them. The capacity of the receptacles is purposely limited, so as to prevent accumulation for any length of time, and necessitate frequent removal of the sewage. Unless a very considerable amount of care is exercised by the householder, and the scavenging arrangements are complete, and unless regular and constant supervision is maintained, the closets are sure to become nuisances of the worst description, rivalling the old-fashioned ash-pits and middens which were, and still are in some places, the abominations of English towns.

Dr. Radcliffe gives as his opinion founded upon a wide range of experience, that "in all forms of fixed closets the foremost condition—the one to which all other considerations should yield—is the *frequency of removal of deposited excrement.*" The complete removal of all excrement within a day, he considers as practically constituting safety in the case where the material is unmixed, or is only mixed with ordinary ashes, and he, with Dr. Buchanan, recommended this view to the authorities of Hull; but, thus far, a weekly removal is all that has been attempted.

The ash-closet system may fail in its sanitary objects through faulty construction or deterioration of the walls of the pits, leading to imperfect cleansing, and perhaps to the escape of liquid filth into the soil. Or, its designs may be defeated by the want of care and cleanliness, particularly on the part of the ignorant and improvident classes. The use of the privy-pits as receptacles for house-slops is inevitable in a certain number of cases. It can hardly be prevented, except by an amount of supervision which, ordinarily, it would not be practicable to provide. This practice hastens the decomposition of the excrement, and may lead to an occasional overflow of the receptacle, and to all the evils attendant upon a bad form of cesspool.

All these disadvantages have been experienced at Hull, which has perhaps the best system of ash-closets or vaults (fixed receptacles) that has as yet been adopted by any town of considerable size.

The dry-ash method has never been systematically introduced in any town in this country that we are aware of, nor is it desirable that it should be, unless as an improvement upon the common privy-well or cesspool. For small towns, where some form of conservancy must be depended upon, the dry-earth system offers far greater advantages. In large towns, unless impracticable, the water system should be adopted as being "the cleanest, the readiest, the quickest, and, in many cases, the most inexpensive method" of removal of excreta. In regard to large cities, the question has already been practically settled.

3. *Other Systems.*

Privy-vaults and cesspits.—It would be a waste of time to describe these forms of receptacle for the accumulation of human excrement. Unfortunately, the public are already too familiar with these nuisances, which have their place in every city, town, and hamlet in the land. It has already been shown that privies of the accumulative sort are injurious to health, and should be discontinued, especially in populous places. It is idle to hope for this much-needed reform until public opinion is more enlightened upon sanitary topics, and our local authorities are clothed with more ample and peremptory powers. In the meantime, "all that can be attempted is to reach such a modification of the methods now in use as shall render them at least much less offensive and dangerous than they now are."

The simple pail system.—This is one of the systems which has been put forward as an amendment of the system just alluded to. It has for its aim "that the excremental matter, unaltered, shall be removed from the privies at so short intervals as not to have become offensive; and adopting as a means to this end the use of movable receptacles, which systematically, at short intervals, are to be changed, clean for dirty by the scavenger; and which, for the prevention of nuisance in this process, have close-fitting air-tight lids to be applied to the foul pails under removal." Dr. Parkes states that this plan is carried out in a part of the city of Glasgow, containing 80,000 people, with satisfactory results. The excrement is removed daily without admixture, except with the ordinary kitchen-refuse, and is transported a long distance with profit. The same plan has been adopted in some English towns, and in a number of cities on the continent.

The *Fosses Mobiles* of Paris are a variety of this system. The pails or barrels are not placed under the seat, but are connected with the closets by means of a descent-pipe, which is usually straight. This main pipe is carried above the building for the purpose of ventilation, and at its lower end rests upon a slab of stone over the receptacle, which is placed in the basement of the building. The connection with the barrel is made by means of a sliding copper pipe which fits in an opening in the lid, so that the excreta are delivered directly into the receptacle. The barrel when full is placed upon a small cart which is moved on rails. Before the removal takes place, the copper pipe is withdrawn from the vessel, and its mouth is tightly secured with a cap and clamps; the lid is then removed, and another covering without any opening is firmly fastened in its place, and the former one is used for the empty barrel, which is placed directly under the outlet of the privy pipe; the copper pipe is then adjusted as before. The work of transfer and removal is quickly and neatly done. The barrels are sometimes fitted with a separator for keeping the fæces and urine apart; the latter may be discharged into the sewer by means of a small pipe.

The "Abfuhrtonnen" of the Germans, are similar to the "Fosses Mobiles" of the French, and consist of wooden or metallic vessels, which are placed directly under the descent-pipes, and when filled are covered with a tightly fitting lid and transported direct to the country, or they are emptied into a vehicle waiting in the street. The removal of the vessels is necessarily frequent, as their capacity is limited. The excrement is either taken direct to the country or is first subjected to a process of manipulation by which it is converted into a manure.

One of the simplest and most satisfactory plans for the removal of excreta without admixture is that adopted at Rochdale. It consists of a closet (outside the house) of simple construction, beneath the seat of which is placed a tub (usually made from a disused petroleum barrel by cutting it in two) to receive the solid and liquid excreta without admixture with any absorbent material. The "pails" are provided with tightly fitting lids so that the process of removal is inoffensive. When one pail is removed, another, which has been thoroughly washed and disinfected at the dépot, is put in its place. The pails are fitted with iron handles so as to be more thoroughly under the control of one man. Having but limited capacity, their frequent removal becomes a necessity. In Rochdale, the weekly removal seems to answer very well. The ashes are collected at the same time and used in the process of manure manufacture. Mr. Taylor, the originator of the system at Rochdale, describes the treatment of the material at the depot as follows: "The pails are thoroughly washed, and into each is put a portion of chloride of alumina and sulphate of lime. The excreta are emptied from the pails into a trench formed of fine ash, which has been sifted from the refuse and cinders collected by the ash-cart. A quantity of sulphuric acid, 30 lbs. to one ton of excreta, is poured into the trench and the whole mixed. In three days the trench is turned over with a spade, and again in twenty-one days, by which time the whole will have become in a tolerably dry state, containing about 35 per cent. of water. Before the sale of the manure it is again turned over and screened. The quantity of excreta to ash used at present is 7 cwt. of ash to 1 ton of excreta.

"The ash-carts pour their contents into the hopper of a sifting machine, which separates the fine ash, fine cinder, rough cinder, vegetable matter, glass, pots, and rags. The disposal of this refuse is by using the fine ash for manure, the fine and rough cinder for fuel for the steam boilers, and for sale; the vegetable matter is burnt, and the ash from it ground and added to the manure for the sake of the potash; the clinkers and pots are ground up for mortar and cement, and the rags, glass, and iron sold."

In some towns the contents of the pails are emptied into carts. If this plan be adopted, a daily removal is required. But this system is needlessly offensive, and does not provide for the cleansing of the receptacles.

Proper attention and frequent removal of the vessels are the principal objects to be aimed at in carrying out the pail system. Upon the observance or the contrary of these essential features will depend very greatly the success or failure of the system.

The simple pneumatic system.—This method, in its best form, consists in the provision of well-ventilated, watertight vaults, of small dimensions, for the collection of solid and liquid excreta to the exclusion of all other waste substances, such as house-slops, kitchen-refuse, etc., which are emptied in an odorless manner, and at frequent intervals, by means of a portable pneumatic apparatus, the so-called "odorless excavating apparatus."

To derive the most satisfactory results from this plan it is necessary that the construction of the vaults with regard to their form, size, location, and other details be under the strictest municipal regulations, and that the subsequent management of the vaults and the removal of their contents be subjected to the most careful sanitary supervision. As a rule, in this country at least, the first-mentioned important requirement is almost entirely neglected, the manner of the construction of the receptacles being left to the discretion of the private householder or builder; consequently, they are almost universally unsatisfactory, and most of them are positive nuisances.

Various kinds of apparatus have been used for exhausting the contents of wells in an odorless manner. Suction power has been applied, the air-pumps used for the purpose being worked either by steam or by hand. In another kind of apparatus, the air in the tank is exhausted by connecting the air-pump with the wheels, so that by the time the receiver arrives at the vault, it is in readiness for filling. In still another arrangement the pumping appliances are dispensed with altogether, and only the receiving cylinder is used. "When about to be employed, this cylinder is filled from a small stationary boiler with steam of about one and a quarter atmosphere pressure, which drives all the air contained in it through a chimney containing a charcoal fire to make it inoffensive. When the cylinder is filled with steam, the valve is closed, the connecting-pipe detached, and the wagon drives to its destination. During the transit the steam condenses, leaving a perfect vacuum above a little water collecting in the bottom. To empty a cesspool it is then only necessary to fasten one end of a hose to a coupling socket on the cylinder, and lower the other end into the pool. The moment the valve in the socket is opened, the air forces the sewage matter into the cylinder, until the gases collecting in the upper part balance the pressure of the atmosphere. The resistance of these gases prevents the filling of the cylinder to more than about three-quarters of its capacity, the suction being very powerful in the start, but gradually slackening off until brought to a dead stop by the above cause."[1]

Within the last few years several highly-improved forms of apparatus have been brought forward, which, having won merited favor, are being rapidly introduced throughout the country.

An excellent form of "odorless apparatus" is illustrated by Fig. 85.

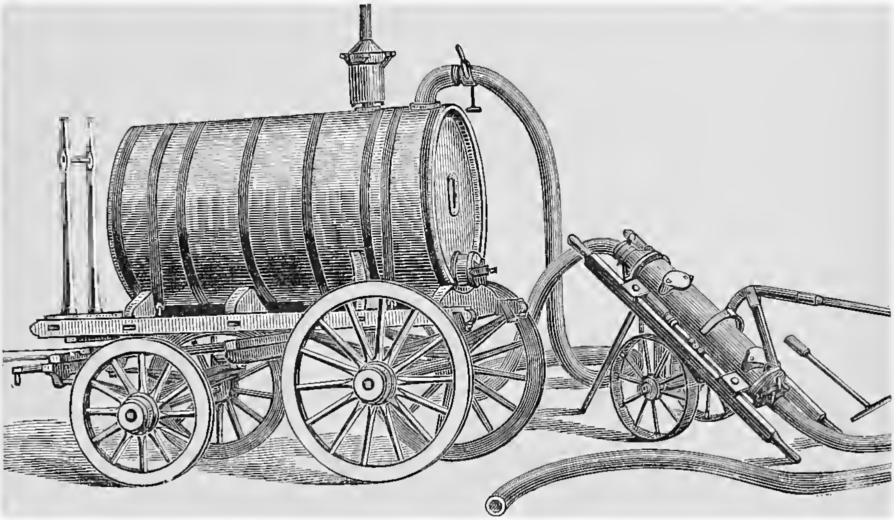

FIG. 85.—Odorless Excavating Apparatus (*Tank System*).[2]

It consists of a pump, hose, a tank, and a charcoal deodorizing furnace for consuming the gases. The tank, having a capacity of about 500 gallons, is made of wood well-braced with iron hoops to add to its strength. It is permanently attached to a truck which is drawn by two horses. At one end of the tank is placed a gauge which is self-acting, and indicates the level of the sewage and the quantity of this material contained in the receiver. A small charcoal furnace is placed over a vent hole upon the top of the tank, and this opening is screened by a wire gauze to prevent ignition of the gases in the receptacle. During the pumping, the foul

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[1] Krepp: The Sewage Question, 1867, p. 83.

[2] The apparatus used by "The Odorless Excavating Apparatus Company."

air displaced by the entrance of the sewage is compelled to pass through the burning charcoal, and is thus consumed without causing any offense.

The pump, which is the invention of Messrs. Painter & Keizer of Baltimore, has great merit on account of the simplicity and efficiency of its valves. The valves, which are of vulcanized rubber, are not easily disarranged, and they are so combined as to give free passage to whatever material is drawn up into the hose. The pump is worked by hand. At one end of it, a four-inch hose is attached and carried into the well. At the other end is attached another section of hose, of the same diameter, which is then connected with the top of the air-tight tank by a patent coupling arrangement which can be quickly and tightly adjusted. When all is in readiness the pump is set in motion, and the contents of the vault are rapidly delivered into the receiving tank without any exposure to the air, and consequently without creating any offensive smells. When the operation is over, the end of the hose withdrawn from the well is cleaned in a barrel provided for the purpose, and the soiled water is pumped into the tank. The hose are disconnected and all the openings in tank, pump and hose are quickly covered with tightly-fitting caps, without the escape of any of the sewage. The whole process from beginning to end is thoroughly, inoffensively, and quickly performed.

There is another description of "odorless apparatus," which is sometimes called the "barrel" system, to distinguish it from the method just described, to which the name of "tank" system has usually been applied. It consists of the following parts:

The pump, *A*.
Pump-receiver, *B*.
Suction-hose and connections, *C*.
Leading-hose and connections, *E*.
Air-hose and connections, *G*.
Barrels and fittings, *O*.
Furnace deodorizer and connections, *H L*.

The pump is placed upon wheels to render its movements more easy. It is used simply as an air-pump, no sewage ever passing through it. Its uses are, first, to create a vacuum in the pump-receiver, and pass the exhausted foul air into the furnace-fire to be consumed; and, second, to compress air upon the contents of the pump-receiver, and force them through the large hose into the barrels upon the truck. The foul air displaced in the barrels is deodorized by being passed through a furnace similar to that connected with the air-pump.

The pump-receiver (*B*) is a strong oak barrel, having a capacity of about forty-five gallons. It is provided with two valves or gates, one near the top and the other near the bottom. The suction-hose which connects the receiver with the vault is attached to the upper one, and the hose leading to the wagon to the lower one. The head of the receiver is provided with a coupling-spud for the attachment of the air-hose.

The barrels (*O*) are strong, forty-five-gallon oak barrels, which have two coupling-spuds in the head—one for the attachment of the leading-hose, and the other for either the air-hose connection or the attachment of the furnace deodorizer, according as the barrel is being filled directly or indirectly. Sealing-caps are fitted to these openings when the barrels are full. The suction-hose (C) and leading-hose (E) are made of rubber, and have an inside diameter of three inches. The former is lined with spiral, galvanized flat iron or brass wire to prevent collapse. The couplings are simple and readily adjusted. In operating the apparatus, the pump, pump-receiver, deodorizer, and fittings are brought close to the vault. If the material is to be transferred from the pump-receiver to barrels, these are in readiness upon a truck in the street, and are connected, one after another, with the receiver by means of the leading-hose.

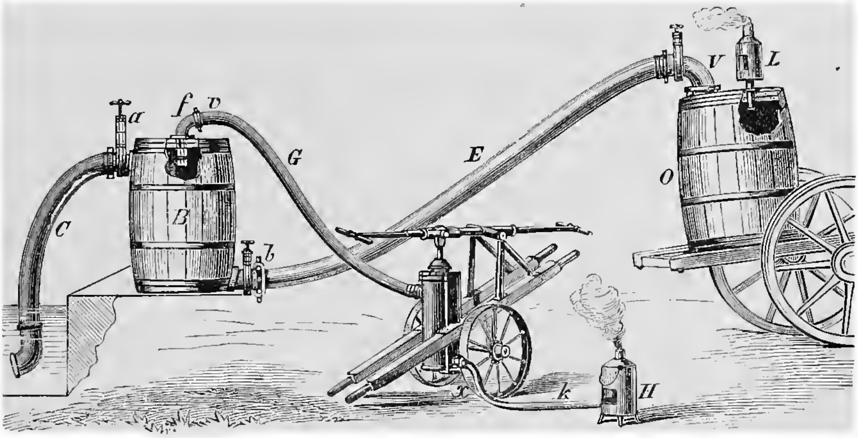

Fig. 86.—Odorless Excavating Apparatus (*Barrel System*).[1]

When all the parts of the apparatus are properly arranged, and all the couplings and connections have been made air-tight, the manner of working the apparatus is as follows:

"Lift the gate, a, on pump-receiver, B; see that the lower gate, b, is shut *tight.* Work the brakes, when the air will be exhausted from the receiver *viâ* the float-valve opening and air-hose, fv. The contents of the vault will at once rise through the suction-hose, C, into the receiver, till the material lifts the cork float-valve and stops the pump, the receiver being full. Instantly shut the upper gate, a. The foul air exhausted from B has passed through the pump and short air-hose, k, under the fire in the deodorizer, H, and is consumed.

"To transfer the material to the barrels or tank on the wagon, uncouple the end of air-hose, G, from the suction-spud of the pump. Remove the free end of air-hose, k, from the throat of the deodorizer, and couple the ends of k and G together.

"Have goose-neck valve, V, on the wagon-barrel lifted. Lift lower

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[1] The apparatus used by "The Ames Eagle Odorless Excavating Apparatus Company."

gate, *b*, on receiver, and work the brakes, when the compressed air, driven in at the top of the receiver, will rapidly force the contents through the leading hose into the wagon-barrel. When the wagon-barrel is full, its float-valve will be lifted, and the roar of the wagon-deodorizer, *L* (which has consumed the foul air forced from the barrel), will cease.

"The goose-neck valve, *V*, and deodorizer, *L*, may now be coupled with the next wagon-barrel, and the process resumed as described. If a long line of leading hose is used, it will be necessary to reserve one wagon-barrel for its contents, or it may be returned on itself, and the contents discharged into the vault."[1]

By this method the barrels may be filled either at the vault or at some distant point, whichever may be more convenient. There is another advantage which this method has over the "tank" system; namely, the facility with which the sewage can be transported by wagon, boat, or rail without causing any offense, and delivered to farmers at a distance in convenient quantities for immediate application to the land. This method is likewise neat, inoffensive, ready and efficient, and commends itself to the favor of the authorities where vault emptying is still practised.

These two examples represent two styles of apparatus now in practical operation in many cities. There are differences in the mechanism of the pumps, and in the arrangement of the parts of the apparatus, and in the kind of receptacle and deodorizer, but the same general principles are applied in all the different apparatuses.

The privy-vault system is an exceedingly objectionable one, unless made to conform absolutely to the most stringent regulations which, in practice, it is found almost impossible to carry out. But where the use of privy-vaults and cesspools is still persisted in, it is the duty of the sanitarian to indicate, and of the public authorities to put into operation, the very best appliances that can be devised for mitigating or preventing the annoyances and dangers which attend the revolting practice of emptying these receptacles by hand, shovel, and bucket.

Some of the objections to the vault-system are—that the walls of the receptacles, however well built and tightly cemented in the first place, are liable to become deteriorated either from the action of the sewage, the settling of the ground, or by the influence of frost, and allow more or less of the sewage to escape into the soil and into wells used for water-supply, to the detriment of the public health. The pollution of the air of dwellings by the evolution of noxious gases resulting from the decomposition and putrefaction of the sewage matter, especially when accumulated in large volumes and retained for a long time, is another serious objection to this system.

From an agricultural view-point, the value of excremental matter after fermentation and putrefaction has taken place, which is invariably the case when the retention is of long continuance, is greatly diminished,

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[1] Ames: Eagle Odorless Excavating Apparatus, Boston, 1878, p. 30.

and the material is rendered almost worthless for fertilizing purposes (Krepp).

The emptying process need not be offensive if the vaults are used for the purposes for which they are intended. But if ashes, garbage, crockery, and refuse of every description are thrown into them, resort must be had to "*pitting*," which, even in its best form, is an exceedingly offensive and objectionable operation.

The Liernur pneumatic system.—This ingenious and novel plan has recently been brought to public attention as a solution of the great problem of town sewerage. It consists in the provision of air-tight tanks which are placed at convenient distances, under the street crossings, and are connected with the closets of houses by means of air-tight pipes. These district reservoirs are again connected with other reservoirs, located at a central station, by a separate system of air-tight pipes. By means of these pipes the air is exhausted from the local reservoirs by an air-pump worked by a steam-engine, and the sewage is drawn along the pipes to the central reservoir, and is then converted into a fertilizing powder, or transferred to barrels for transportation to the country.

The following description of the plan and the details of its operation by Mr. Adam Scott, is taken from a paper on "The Disposal of Sewage" by Dr. Folsom:[1]

"In a building, in any convenient part of the town, is placed a steam-engine, which drives an air-pump, so as to maintain about three-fourths vacuum in certain cast-iron hermetically-closed reservoirs sunk below the floor. From these reservoirs central pipes radiate in all directions, following the main streets. On these central pipes are laid, from distance to distance, street reservoirs sunk below the pavement. From the street reservoirs, up and down the street, are main pipes communicating by short branch-pipes with the closets of each house.

"All the junctions of pipes with reservoirs are furnished with cocks, so that they can be shut off or turned on at pleasure, like water-mains, and are got at by cock-boxes, and turned by keys in the ordinary way. The vacuum created in the central building reservoirs can thus be communicated to any given street reservoir, so as to furnish the motive-power by which, when the connections with the houses are opened, all the closets are simultaneously emptied.

"When their contents reach the central reservoir, they are in like manner forced through the central tubes to the reservoirs under the central building, and thence transferred, by means of vacuum-power, to hermetically-closed tanks above the floor of the building. From these retorts the matter is again decanted in a fluid form in barrels, for immediate transport to the country, by means of hermetically-closed apparatus.

"During the construction of this system, and before connections are made with the central building, a locomotive engine empties the different

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[1] Seventh Annual Report of Mass. State Board of Health, p. 313.

street reservoirs, and the closets connected therewith, by means of a hose from the tender to the reservoir.

"Closets of the simplest possible character are all that are required, and no water whatever is needed. The funnel is made double, the space between the two communicating by a pipe with the outside air.

"The excrement falls into a sort of hydraulic trap, capable of holding the fecal products of but one person, and compelling thus what it held before to fall into a larger trap of four times greater capacity. This latter discharges in the branch tube, which is connected with the main tube, and empties into the street reservoir.

"The branch tubes from the houses are laid with a succession of grades, not less than one in ten, rising at every twenty feet by a short syphon-tube, two feet high, to the beginning of a new grade, until it falls into the main tube. It is by means of these continually repeated short bends that the removal of the contents of so many privies, by turning only one cock on a main pipe, is possible, whether or not any are empty on account of the house being uninhabited. The fecal mass itself practically forms the required temporary closure from the main pipe, allowing, through its inertia, all the branch pipes to be simultaneously and equally acted upon under all circumstances. All metal valves formerly employed for this purpose, and likely to get out of order, are now done away with.

"The main pipes, into which the branch pipes discharge, are laid with a fall of one in seventy-five, without any break until near the lower end, when they are suddenly bent upward by a syphon-pipe, so as to reach the upper part of the reservoir. On the upper part of the syphon is placed the cock which connects or disconnects the main tube with the reservoir.

"The central tubes, which lead directly from the reservoirs to the central building reservoirs, communicate with the lower part of the former by means of short pipes, and proceed in grades of one in a hundred, broken every hundred metres by a syphon rise."

This system has never been tried in England, nor has it met with any favor in the United States, although it has been widely heralded. On the continent partial experiments have been made, but no town or city has applied the method on a very large scale.

Both in Prague (1868) and Hanau, where it has been tried on a small scale, the judgment was unfavorable, though Capt. Liernur has stated that the objectionable parts have since been remedied by improvements in the system.

In Leyden a portion of the city inhabited by the poorer classes was supplied with this system. It was found to be an improvement upon the old plan of throwing the filth into the canals, but it has not been further extended.

In Amsterdam it was likewise introduced in the poorer parts of the city, where no provision for sewage had ever been made, the canals having been used for all refuse which could not escape by surface-drainage. Here the results are said to have been satisfactory, though no steps have been taken toward the general introduction of the works. The better classes are said to prefer water-closets and cesspools (Folsom).

Other places on the continent have experimented with the method; among the number are Brünn, Olmütz, and St. Petersburg, and the results of the trials have been variously reported on.

It is objected to the system that the pipes are apt to become clogged with fecal matter, and that the closets are often very offensive. Sometimes the closets become completely obstructed, when the stench is intolerable. To overcome this annoyance flushing is resorted to, and among the better classes water is very freely used, though only a limited quantity is allowable; the result is a deterioration in the strength of the sewage and an increase in the cost of disposal. Dr. Folsom states that Capt. Liernur purposes to overcome this difficulty by providing automatic water-closets, allowing one litre of water at each use.

With the Liernur system, sewers for rain-water, street drainage, house slops, etc., are still necessary.

The system certainly possesses considerable merit, and might be advantageously used in localities where the disposal of excreta by water-carriage is impracticable. It is perhaps too soon to pronounce decidedly upon the practical working of the scheme, since many of the objections urged against it may in time be remedied by mechanical improvements which might place it in a very different light.[1]

The different systems compared.—The question of the best method of disposal of sewage, abstractly considered, is not a difficult one to solve. But when all the circumstances of place are taken into consideration, it is evident that no one system can be singled out as applicable in all cases. Local conditions must necessarily be consulted before determining the best method to be adopted. The best method for one locality may be altogether impracticable for another locality.

It has already been pointed out, that where all the circumstances are favorable the water-carriage system, by which a neat, ready, and quick disposal of the sewage is ensured, is unmistakably the best adapted for large towns. It will be generally admitted, that, for such places, the provision of sewers to carry off the waste fluids from dwellings, the refuse from trades, and street-washings, etc., is an absolute necessity. The only point of dispute is whether the excreta shall also be added. It has been seen, that, even without the admixture of solid excreta, sewage is an exceedingly impure substance, and must needs be purified before being admitted into streams. The difficulty really resolves itself into the treatment of an increased volume of sewage required where water-closets are in use. It is simply a question of additional expense, which, as an objection, falls,

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[1] See Krepp: The Sewage Question, 1867.

Die pneumatische Canalisation in der Praxis, von Capitain Liernur, Frankfurt, 1870.

Seventh Annual Report Massachusetts State Board of Health, p. 311.

Waring: Sanitary Drainage, p. 284.

Deutsche Viertelj. für. off. Gesundheitspfl., Bd. iv., S. 316 u. 486.

when the cost of a separate system for excrement removal is taken into consideration.

The main objections to sewers are founded upon faults in their construction. But the objections are not valid. A faulty piece of mechanism is never taken as a standard by which to judge of the efficiency of a more perfect example. It speaks only for itself. If sewers are constructed in the best possible manner, if the outfalls are carefully selected, if the house arrangements comport with standard regulations, if the water-supply is ample; and if all the details of the system are thoroughly carried out under the best engineering skill, sewers cannot be hurtful even with the addition of the solid excreta which do not materially increase the impurity of the sewage.

Small towns and villages cannot avail themselves of the benefits of the sewerage system, on account of the expense of constructing the works and of providing the necessary water-supply. In such cases the dry conservancy system, invariably combined with frequent removals, should have the preference. Some form of dry-earth closet or charcoal closet will meet the wants in a satisfactory manner. In rural districts the dry-earth system, if properly carried out, will meet every requirement. In sea-side towns, where the proper kind of earth cannot be cheaply obtained (sand cannot be used as a substitute), some other form of dry removal may be resorted to. The simple pail-system would certainly be a great improvement upon the pits in general use, which are purposely constructed to allow the liquid filth to drain away into the soil to save the expense of removal. Small cast-iron reservoirs might be provided in the place of cemented brick-vaults (which cannot be depended on as being water-tight), from which everything except solid and liquid excreta should be excluded. The reservoir should be placed under a well-ventilated privy-house. If it is desired to connect it with a closet projecting from the house, and separated from it by a well-ventilated space, the descent-pipe should be as direct as possible, and the basin should be of plain glazed earthenware of the hopper pattern. This could be kept clean by the use of the chamber-water. The connection between the reservoir and the pipe might be hermetically sealed by a valve, to be opened by a lever once a day. When full, the reservoir should be emptied by means of the "odorless apparatus" already described.

The Disposal of Sewage.

It has already been shown that the water-carriage system is, as a rule, the best method for getting rid of excreta and other refuse matters. The question of the ultimate disposal of the sewer-water is yet to be considered.

The most natural mode of getting rid of this material is by discharging it directly into the ocean or into the nearest watercourse; and this is the disposition almost invariably made of it in this country, and, with some exceptions, in other countries. In England, under the Rivers' Pollution Act, the discharge of sewage into any river or stream, without previous purification, is now prohibited so far as relates to all new drainage-works.

There are several objections to the disposal of sewage by allowing it to flow directly into rivers or streams. There is the danger of silting up the beds of streams by the deposit of substances suspended in the sewage. This has actually occurred in the river Thames, where extensive shoals were formed below the outfall. Before the present sewerage works were constructed, the accumulations were so rapidly forming as to seriously threaten the safety of navigation. In small streams, though not navigable, this danger may prove to be a most serious one. In tidal rivers the suspended matters are carried up stream as well as down stream, unless the outflow is regulated so that the discharge takes place only with the descending current. Even with this precaution it is shown, by Mr. Bazalgette, that a portion of the solid matters contained in the sewage, and carried down to a certain point by the ebbing tide, is returned again by the ascending tide and deposited above the point of discharge. Large sums of money are annually expended for dredging out deposits from sewers along our city fronts. This is the constant result of the exceedingly bad practice of thus improperly locating the sewer outlets. By the use of intercepting sewers, having an outfall at a distance below the town, this inconvenience and expense could be avoided.

Another objection is that valuable stocks of fish are destroyed by discharging sewage into streams. Sewage in the fresh state, or when very much diluted, as is the case in our large rivers, is probably not hurtful. It is the gases produced by the decomposition of the deposits, particularly sulphuretted hydrogen, that are said to be the hurtful agents. The agriculturist opposes the plan on the ground that a vast amount of valuable fertilizing material is thus turned to waste. If the cost of reclaiming the fertilizing ingredients of sewage is greater than the value of the material recovered, " then the true economy is found in the apparent waste." The exhalation from streams overcharged with sewage may become a nuisance, and the deposit of organic matters upon the banks of rivers, and their exposure by the receding tide, may be a source of annoyance, if not of positive danger.

But the most serious objection arises from the contamination of the drinking-water of towns located further down the streams. Corfield mentions cases in England where towns actually turn their own sewage into rivers only a short distance above the point from which the water supply is taken. This is not an uncommon practice in the United States.

Generally speaking, in this country the instances are rare where any towns have seriously suffered from the effects of this mode of sewage disposal. Most of our cities and large towns are situated either along the seaboard or upon great rivers or lakes, where large volumes of water are always available. But as the country develops other places not so favorably situated will be obliged, for self-protection, to solve this most important problem by the adoption of some plan for the purification of sewage. Already one of our States, recognizing the great importance of protecting the health of its citizens, has, by "an act to provide for an investigation of the question of the use of running streams as common sewers in its relation to public health," set on foot an inquiry which has produced highly interesting and most valuable reports covering this entire subject, to which reference may be made with advantage.[1]

The methods of disposal of sewer-water are various. They may be briefly alluded to as follows:

1. *Discharge directly into running streams.*—This is the plan resorted to in the United States, and it will probably be permitted for some time to come where the volume of water is large, and where it is not immediately used for drinking purposes. In all other cases there is good and sufficient reason for the adoption of some plan for the purification of sewer-water before it is allowed to flow into the stream. In England no new sewage-works are permitted to discharge directly into running water, and works in existence at the time of the passage of the act will eventually come under the same stringent regulation. These regulations are based upon the results of extensive and varied experiments carried on for many years, which have demonstrated the feasibility of plans for depriving sewage of its foul and noxious matters, so that it may be discharged into rivers without causing a nuisance, "without making the water too impure for use in manufacturing operations; without killing or driving away the fish which may inhabit them; in short, without materially injuring them for any purpose, except as sources of water-supply for cities or towns."

2. *Discharge into the sea.*—This mode of disposal may be adopted with safety, provided that the sewage can be delivered in deep currents or that the outfall can be carried far out to sea, so that the sedimentary matters and floating bodies shall not return again to pollute the shores or form deposits of an objectionable character. In sea-bathing towns it may be necessary to clarify the sewer-water before allowing it to flow into the sea.

The impounding of sewage within the outfall sewers during each tide is an objectionable feature in the sewage-works of seaboard towns. There is a liability to the formation of deposits in the sewers on account of the frequent checking of the discharge, and from this same cause there is greater danger of the formation and escape of noxious gases than when the outflow is constant. A constant outflow, whereby these evils will be avoided, may be secured by the application of steam power to raise the sewage and dispose of it independently of the state of the tide. The outlets should be protected by flap valves, in order to regulate the action of the winds.

The disposal of sewage by allowing it to run as mere waste into river estuaries and into the sea is certainly the most convenient, the cheapest, and, generally, a perfectly safe method of riddance. Should this plan give rise to a nuisance in spite of the best engineering arrangements, the

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[1] Seventh Annual Report of State Board of Health of Massachusetts, 1876.

sewage may require to be dealt with by some simple plan of purification before its discharge.

3. *Precipitation.*—There are several plans for separating a portion of the suspended matters from the liquid sewage before applying it to land or allowing it to flow into the river. One of these is by mechanical subsidence, the sewage being collected in tanks, or reservoirs, where the suspended matters are intercepted and deposited by the aid of strainers to impede the flow. The matter thus collected is treated with various kinds of refuse to form a manure. This is an unsatisfactory plan, inasmuch as the sewer-water is still highly impure, and, therefore, should not be permitted to flow into rivers from which untreated sewage is excluded. A more effectual purification may be secured by means of chemical agents. By these processes, not only are the suspended matters separated, but also a considerable proportion of the substances held in solution. The material thus obtained is manipulated into a solid manure, but thus far without financial success. It is also a question whether the effluent liquid is sufficiently purified to be allowed to flow into a stream or river, the waters of which are used for domestic purposes.

The methods which have been suggested at different times are very numerous. Those of most importance are as follows:

a. *The lime process.*—This process consists in adding lime—in a creamy condition—to the sewage, in the proportion of from three to sixteen grains of lime to a gallon of sewage. A flocculent precipitate is thus formed, which in the course of an hour settles to the bottom of the tank, leaving a tolerably clear, supernatant liquor, which is said to be comparatively inoffensive. The precipitate is sold as a manure, or is converted into bricks. By this process about 50 per cent. of the dissolved organic matter contained in the sewage is removed. The process of drying the precipitate is said to be very offensive, on account of the escape of sulphuretted hydrogen. The defæcated sewer-water also becomes offensive if allowed to stand for any length of time; and, therefore, to prevent secondary putrefactive change, it is necessary to mix it with a large volume of flowing water. Various substances have been added to delay putrefaction, such as charcoal, chloride of lime, and carbolates of lime and magnesia; but their use is expensive and only of temporary value. This process was carried out on an extensive scale at Tottenham and Leicester; but, as the product had but very little agricultural value, the works were soon abandoned by the patentees and transferred to the town authorities, who, by neglect, brought the method into disrepute.

It is said that the river Soar, at Leicester, which had become a foul and pestilential stream, presented an entirely different character after the lime process had been adopted, "for aquatic plants had begun to flourish, the fish had returned, the black mud had ceased to accumulate, and the milldam was no longer offensive."[1] This indicates a great improvement in the character of the sewage, which is an invariable result whenever the

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[1] Letheby: The Sewage Question, 1872, p. 46.

method has been well conducted. But as so large a proportion of organic matter still remains even after the most careful treatment, it is evident that the liquid sewage is not sufficiently purified to be admissible into a river. The Rivers' Pollution Commission have declared the plan to be a failure, "whether as regards the manufacture of valuable manure, or the purification of the offensive liquid."

b. *The alumina processes.*—The salts of alumina have been used for the purification of sewage, the different processes which have been invented depending on the well-known property of alumina to combine with organic matters, with which it forms insoluble compounds. The results of this method are not unlike those obtained from the lime process. The effluent water is clarified and deodorized, but only partly deprived of its dissolved organic matter. The process is a more costly one, while the precipitate possesses less manurial value.

c. *Blyth's process.*—A solution of phosphate of magnesia, in combination with lime or some other precipitating agent, is added to the sewage, with the view of precipitating the ammonia-phosphate of magnesia, which carries with it the matters suspended in the liquid. This method is said to be a costly one, and there is doubt as to its efficiency.

d. *The "A B C" process.*—This process, patented by the Messrs. Sillar, takes its name from the initial letters of the substances mainly used for the purification of the sewage—namely, *A*lum, *B*lood, and *C*lay. The proportions of the agents used are: "Alum, 600 parts; clay, 1,900 parts; magnesia, 5 parts; permanganate of potash, 10 parts; animal charcoal, 15 parts; vegetable charcoal, 20 parts; and magnesian limestone, 2 parts." These materials are thoroughly mixed together, and are added to the sewage to be treated until no further precipitation can be produced. The quantity usually required is about four pounds of the mixture to one thousand gallons of sewage. The effluent water is said to be clear and quite inodorous; but it contains, according to the results of a series of chemical examinations, on an average 9.17 grains of dissolved organic matter per gallon of sewage, the average quantity per gallon of raw sewage being 16.21.[1]

Dr. Folsom gives[2] the results of the examination of the Sillar process by the Rivers' Pollution Commission as follows:

"1. The process precipitates the greater part of the solid particles of the sewage, but in no case to such an extent as to allow the superincumbent waters to run into a river.

"2. The process produces no clearer water than what would have resulted if the sewage were allowed to settle by itself.

"3. The sewage is considerably reduced in value by it.

"4. Bad smells are always perceptible."

e. *Holden's process.*—In this process sulphate of iron, lime, coal-dust, and clay are added to the sewage, with the effect of precipitating nearly

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[1] Letheby: The Sewage Question, p. 88.

[2] Seventh Annual Report Massachusetts State Board of Health, p. 332.

all of the suspended matters and at least half of the dissolved organic matter. The supernatant liquor is quite clear and inoffensive. "The precipitate, when dried in the air, contains about 43 per cent. of organic matter, and rather less than one per cent. of phosphate of lime. The organic matter is not very rich in nitrogen, and, therefore, the manure is not of much value."

f. *Anderson's process.*—Crude sulphate of alumina and lime are used in this process. The sulphate is formed by adding one part of sulphuric acid to two parts of clay, then mixing the materials with an equal bulk of water. After standing for some time, the mixture is added to the sewage in the proportion of one pound of the former to one hundred gallons of the latter. The liquid is then thoroughly agitated, after which a quarter of a pound of slaked lime is added, and precipitation takes place. Dr. Voelcker analyzed the effluent water after being treated in this manner, and says of it, that "it is so thoroughly deprived of obnoxious impurities that, in my opinion, it may be discharged into a running stream or watercourse without risk of creating a nuisance." *Bird's process* is very similar to the above. *Stothert's* consists in the addition of sulphate of zinc and charcoal to the sulphate of alumina.

g. *Precipitation by the perchloride of iron.*—This method has been reported on favorably by Drs. Hofmann, Frankland, and Miller. It is said to have a marked superiority over caustic lime and chloride of lime—the deodorizing effect being in the order named. In all cases, it is recommended that the suspended matters precipitated by these agents should be promptly removed, as no doubt the chief cause of the offensive odor of the sewage, some days after it has been deodorized, is due to decomposition of the organic matter contained in the precipitate. The solution of perchloride of iron generally used is called Dale's liquid.

h. *The phosphate process.*—The sewage is treated with an acid solution of the phosphates of alumina, either alone or in combination with lime or carbonate of lime. The result is the precipitation of the suspended matters and a considerable proportion of the soluble organic matter. The value of the precipitate has not been determined. This process, like many of the others, may be used where the effluent water is intended to be discharged into the sea or tidal estuaries, or as a preliminary to irrigation.

i. *General Scott's process.*—The chemicals, such as lime and pulverized clay, are introduced into the sewers some distance from the outfall. By the time the sewage reaches the tanks it is found to be deodorized. The suspended matters are collected at these depositories, and are subsequently dried and burned without offence, and the product is converted into a cement of good quality. The effluent water is not sufficiently pure to be discharged into streams, and must be used for irrigation, or be filtered before discharge.

The clarified sewer-water obtained by all these processes contains ammonia and dissolved organic matters, as well as potash, and, in most cases, phosphoric acid, and it therefore possesses considerable fertilizing power. The purified effluent water may be applied directly to the land. It is particularly well adapted for the irrigation of market gardens. Clarified sewage may be discharged at once into the sea or into tidal estuaries. It is safer to keep it out of rivers or streams from which the water-supply for domestic purposes is taken, at least until after it has been subjected to filtration.

4. *Filtration.*—Filtration is the mechanical separation of the liquid from the undissolved particles of the sewage, by passing it through beds of porous earth, sand, gravel, charcoal, etc. In its simplest form, the sewage is merely strained, so as to remove most of the suspended matters; but the effluent sewer-water is not purified to any extent.

Filtration may be both upward and downward. Upward filtration is not at all satisfactory, for the reason that the filter-bed is always charged with water and is therefore incapable of aërating the sewage. It is now seldom resorted to. Downward filtration, provided that the process is intermittent, is capable of effecting a very satisfactory purification of sewer-water.

Oxidation of the organic matters contained in sewage takes place by virtue of the presence of air in the filter; hence it is necessary that the ground be alternately exposed to the air and the sewage.

The experiments conducted under the direction of the Rivers' Pollution Commission led to the following conclusions:

"Sewage, traversing a porous and finely-divided soil, undergoes a process to some extent analogous to that experienced by blood in passing through the lungs in the act of breathing. A field of porous soil, irrigated intermittently, virtually performs an act of respiration, copying on an enormous scale the lung-action of a breathing animal; for it is alternately receiving and expiring air, and thus dealing, as an oxidizing agent, with the filthy fluid passing through it. The action of the earth as a means of filtration must not be regarded as simply mechanical; it is chemical, for the results of filtration, properly conducted, are the oxidation, and thereby the transformation, of the offensive organic substances, in solution in the sewage stream, into fertilizing matters which remain in the soil, and into certain harmless inorganic salts which pass off in the effluent water."

And again: "These experiments also show that the process of purification is essentially one of oxidation, the organic matter being to a large extent converted into carbonic acid, water, and nitric acid; hence the necessity for the continued aëration of the filtering medium, which is secured by intermittent downward filtration, but entirely prevented by upward filtration."

From his experience gained at Merthyr Tydfil, Dr. Dyke lays down the following necessary conditions:

1. The soil must be porous.
2. A main effluent drain, not less than six feet from the surface, must be provided.
3. The inclination of the ground should be such as to allow the sewage to flow over its entire surface.

4. The division of the filtering area into four equal parts, each part to receive the sewage for six hours, and then an interval of eighteen hours to elapse before the second irrigation takes place. An acre of land thus prepared would dispose of 100,000 gallons of sewage per day.

The process is more successful when the sewage has been screened, so as to arrest the coarser matters before the water is applied to the filtering area. It is also necessary that the filtering material should be large. Parkes says that it must not be less than one cubic yard for eight gallons of sewage in twenty-four hours. The Rivers' Pollution Commissioners make the proportions somewhat less (1 cubic yard to 5.6 gallons). In proportion as the rate of filtration is increased, the purification becomes unsatisfactory and uncertain.

Small filters are useless, and this may account for the failure of filtration through charcoal. This material has never been employed on a large scale. Soils containing oxide of iron and silica are considered the best for filtering purposes. Sand or a mixture of sand and chalk are also very effectual.

5. *Irrigation.*—The distribution of sewage over the surface of the soil, with the view of bringing it speedily under the influence of plants, is a method often resorted to for its utilization and purification. The sewage is applied directly to the unprepared land, without any provision having been made for underground drainage, or it is made to pass through the soil, and the effluent water is carried off by deep drains. The former plan cannot be said to be satisfactory, especially in seasons when vegetation is inactive, the effluent water passing from the surface of the land thus irrigated often being only little better than diluted sewage, and, in some cases, highly impure. In the Third Report of the British Association, mention is made of an instance (at Reigate Farm) where the sewage which had passed over one field was actually rendered more impure in several ways by passage over a second field. The saturation plan depends entirely upon the purifying action of luxurious vegetation. In winter this action is suspended or only partially effected.

By the other plan, in which *filtration* is combined with *irrigation*, the sewage can be satisfactorily purified at all seasons of the year, during winter as well as in summer. Unless the ground is naturally porous, it must be made so by artificial means. Recourse must be had to deep drainage, and, where the soil is stiff and clayey, it may require the addition of ashes, sand, or lime. "Irrigation farms are nothing more nor less than filter-beds on a very large scale." Irrigation must be intermittent, in order to insure proper aëration of the soil and purification of the sewer-water. It is evident that vegetation does not prosper in a water-logged soil, and it has been shown, on the other hand, that purification by filtration is very imperfectly performed, unless frequent and free access of air to the surface of the filtering area is permitted.

The British Association Committee, in the report already alluded to, express their opinion of the value of subsoil drainage, in connection with irrigation, in the following words:

"It may seem almost superfluous for the committee, after so many years of general experience throughout the country, to argue in favor of the subsoil-drainage of naturally heavy or naturally wet land, with impervious subsoil, for the purposes of ordinary agriculture; but some persons have strongly and repeatedly called in question the necessity of draining land when irrigated with sewage; and the two farms at Tunbridge Wells, to a great extent, and more especially the Reigate Farm at Earlswood, have been actually laid out for sewage irrigation on what may be called the 'saturation' principle; so that it appears to the committee desirable to call attention to the fact, that if drainage is necessary where no water is artificially applied to the soil, it cannot be *less* necessary after an addition to the rainfall of one hundred or two hundred per cent. But a comparison of the analyses of different samples of effluent waters, which have been taken by the committee from open ditches into which effluent water was overflowing off saturated land, and from subsoil drains into which effluent water was intermittently percolating through several feet of soil, suggests grave doubts whether effluent water ought ever to be permitted to escape before it has percolated through the soil."

The effect of passing sewer-water through the soil is stated by Parkes[1] to be as follows: "1. A mechanical arrest of suspended matters. 2. An oxidation producing nitrification, both of which results depend on the porosity and physical attraction of the soil. 3. Chemical interchanges. The last action is important in agriculture, and has been examined by Bischof, Liebig, Way,[2] Henneberg, Warrington, and others. Hydrated ferric oxide and alumina absorb phosphoric acid from its salts, and a highly basic compound of the acid and metallic oxide is formed. They act more powerfully than the silicates in this way. The hydrated double silicates absorb bases. Silicates of aluminium and calcium absorb ammonia and potassium from all the salts of those bases, and a new hydrated double silicate is formed, in which calcium is more or less perfectly replaced by potassium or ammonium. Humus also forms insoluble compounds with these bases. Absorption of potash or ammonia is usually attended with separation of lime, which then takes carbonic acid."

The sewage is brought to the land to be irrigated either by gravitation or by pumping. It should be in as fresh[3] a state as possible, and, before its application, should be freed from its scum and its grosser suspended matters. This may be effected in tanks by simple filtration or screening, or by one of the simpler processes of precipitation. The sewage is conveyed from the tanks to the land, or, when it has to be pumped, from the pumping-well, in "carriers," which are either simple trenches, or channels made of concrete, brick-work, or earthenware. According to Corfield, where the sewer-water has to be lifted up by pumping, sheet-iron carriers, supported on wooden tressels, are the best. The carriers are provided with dams and gates to regulate the direction and flow of the sewage, and with simple taps, which may be opened by taking out a plug.

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[1] Op. cit., p. 383.

[2] Journal of Royal Agricultural Society, Vol. XI.

[3] Carbolic acid is sometimes added to prevent decomposition.

Flat land, or land which gently slopes, is the best for irrigation. It should be laid out in broad ridges and furrows. The sewage is conveyed along the crests of the ridges in open carriers, which are supplied by the main carriers from which they branch off at right angles. When the small open carriers are full, the sewage overflows and runs gently down the slopes, and is absorbed by the soil and carried off into the nearest watercourse by drains placed about six feet beneath the surface.

The amount of sewage disposed of in this way by a given quantity of land, will depend upon the porosity of the soil, the amount of rain-fall, and the time of the year. The amount of land set apart for sewage irrigation should not be less than one acre to one hundred and fifty inhabitants; if the land is of a retentive character, even though there may be good underground drainage, it would be better to provide one acre to every one hundred of population.

Other plans have been suggested for the distribution of sewage. One of these is by the use of hose to sprinkle the land. It is not to be recommended. Another plan is by the use of pipes placed under the ground. Corfield says of this plan, that "it is obviously perfectly absurd. It is impossible to imagine that sewage could be purified by turning it into agricultural drains below the roots of the plants." It can only be applied on a very small scale. Open-jointed pipes are placed about one foot beneath the surface of the ground, and another series of subsoil pipes are laid three feet deeper to carry off the purified liquids. To secure the regular distribution of the sewage, Field's automatic-flush tank may be used. Colonel Waring, who has used this method at Newport, thus describes it :[1]

"The house-drainage is discharged into a tightly cemented tank, four feet deep and four feet in diameter, entering near its top, which is arched over and closed by a tightly fitting stone cap, and thoroughly ventilated. Its outlet pipe, starting from a point one foot below the surface of the water and about two feet below the cap-stone, passes out near the surface of the ground, and is continued by a cemented vitrified pipe to a point about twenty-five feet farther away. Here it connects with a system of open-jointed drain-tiles, consisting of one main, fifty feet long, and ten lateral drains, six feet apart, and each about twenty feet long. These drains underlie a part of the lawn, and are only about ten inches below the surface. During the whole growing season their course is very distinctly marked by the rank growth of grass over and near to them." . . . . "The slope of the ground is very slight, probably not more than fifteen inches between the extreme ends of the system." He subsequently substituted Field's flush-tank for the cemented tank, in order that the discharge might be made intermittent ; the flow of sewage, being more copious, would saturate the soil for a greater distance, and after subsiding would allow the atmospheric air to enter the soil, and aid, by its oxidizing power, in the work of purification.

This system of *sub-irrigation* might be adopted with good results for

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[1] The Sanitary Drainage of Houses and Towns, p. 196.

the disposal of house-slops of separate houses or groups of houses, where land is available.

Various kinds of plants have been grown upon sewage-farms. The Italian rye-grass is perhaps the most suitable crop; but other kinds of grass yield a good return. Cereals have been grown with favorable results. The beet-root raised on sewage has been found to contain a much larger per cent. of sugar than the plants from Holland, Suffolk, and Scotland. Clarified sewage is well adapted for market vegetables, the plants thriving on it ; but raw sewage is sometimes found to be injurious.

Sewage-irrigation in some cases has been remunerative, but it is very doubtful whether it will ever become a valuable source of revenue to any town, however favorably situated. The question of expense is a very important one, and the system should be made profitable or at least self-sustaining, if possible ; but if this cannot be brought about, the pecuniary sacrifice should be endured, in view of the great sanitary advantages of the plan.

The comparative results of the different methods of purification of sewage are thus stated by the Rivers' Pollution Commission :

AVERAGE RESULTS.

PROCESSES.	Percentage of dissolved organic pollution removed.		Percentage of suspended organic impurity removed.
	Organic carbon.	Organic nitrogen.	
Chemical processes	28.4	36.6	89.8
Upward filtration	26.3	43.7	100.0
Downward filtration	72.8	87.6	100.0
Irrigation	68.6	81.7	97.7

The best results are obtained by combining irrigation with intermittent downward filtration. Where land is not available, recourse must be had to some one of the chemical processes, by which the character of the sewage may be greatly improved, though not sufficiently to permit the effluent liquid to be discharged with safety into streams from which potable water is directly obtained, unless the volume of water is very great, and the point of discharge and the point whence the supply is taken are widely separated.

It is alleged that sewage-irrigation farms are dangerous to the public health and interfere with public comfort. If badly managed, they may occasionally be offensive to those living in their immediate neighborhood. Sewage-tanks may become a nuisance, if the sludge is allowed to accumulate or is not properly disinfected before removal. These disadvantages are owing to mismanagement, and can be easily remedied.

If sewage-farms are turned into marshes, after the manner of the plan pursued at Milan, miasmatic fevers may be expected to arise. Such diseases as are common near rice and maize plantations, which are irrigated with river water, may be looked for, but the peculiar constituents of sewage, which give it a distinctive character, have nothing to do with their causation. The sewage commissioners reported, that near Milan "the population who lived in the midst of and close upon irrigated lands are subject to the same diseases as are common wherever extensive tracts of vegetation are alternately covered with water, and then exposed, when comparatively dry, to the action of the atmosphere under a hot sun."[1] No such diseases need occur, and will not occur, if sewage-farms are managed in the proper manner. And the same may be said of the allegation that wells are poisoned and the public health is thereby affected. If the farms are properly arranged, no such danger need be feared. It is perfectly true that sewer water, that has flowed over the land and that has not been filtered through the ground, may be poisonous if drunk, but there is not the slightest possibility of well-water being contaminated, except by the grossest mismanagement.

As to the allegation that diseases usually conveyed by means of the intestinal discharges, such as cholera, enteric fever, dysentery, and allied affections, are produced by effluvia from these farms, little need be said, as it is not borne out by well-substantiated proof. It is true that Dr. Clouston reported several severe and some fatal cases of dysentery in the Cumberland Asylum, supposed to have been caused by emanations from a sewage-irrigated plot of ground less than 400 feet distant; but the method was defective, the soil being composed of stiff clay and not underdrained. Letheby attributed the outbreak of enteric fever at Copley Village to the irrigation of a meadow with water containing the sewage of Halifax. At Eton, enteric fever was supposed to have been caused by sewage effluvia; but it was discovered by Dr. Buchanan that the sewer-water had been drunk.

On the other hand, it is found that these diseases are no more prevalent at the sewage-farms near Milan than elsewhere, and even during the prevalence of cholera in the town and neighborhood, no case occurred upon the irrigated meadows. (Hart.)

At Croydon, Aldershot, Rugby, Worthing, and other places where sewage-farms are well managed, there is no evidence to show that typhoid fever is caused by emanations from these farms. Even in Edinburgh, at the Craigentinny sewage-meadows, which have been notorious as most filthy and offensive plots of ground, no cases of enteric fever have been traced to the effluvia from the irrigated meadows. (Folsom.)

In the light of present experience it may be asserted, "that the effluvia from a *well-managed* sewage-farm do not produce typhoid fever or dysentery or any affection of the kind."

There is still another point to be considered, namely, the alleged danger of the spread of entozoic diseases by means of sewage irrigation. It

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[1] **Hart: Manual of Public Health, 1874, p. 245.**

was supposed by Dr. Cobbold that the risk of parasitic disease in cattle would be very great, if they were allowed to graze upon sewage-farms. And as farms increased, entozoic diseases would become more common, and deaths from these causes would be frequent. But these fears were not well founded. No such results have occurred, at least there is no evidence to prove that these results are more likely to occur from the employment of liquid manure than from the use of solid excreta in the manner so common in the neighborhood of towns. Recent investigations have induced Dr. Cobbold to withdraw this objection to sewage-farms.

To sum up, in the language of Prof. Corfield:[1] "Intermittent downward filtration through soil, and irrigation farming, with passage of the liquid through the soil, are the only means at present known for purifying sewage, and these may be well continued with some deodorizing process, which will prevent the sludge in the tanks from being offensive, except where the tanks are in the open country, where this is hardly necessary; and these processes in themselves are in no way injurious to the health of the neighborhood where they are carried on; one of them, irrigation farming, with the condition mentioned above, also affords the only method known by which the valuable manurial ingredients dissolved in sewage can be utilized—can be turned into wholesome food for man and beast. . . . The removal of waste matters is the first thing to consider, their utilization the second; where you have both, there you are best able to compete with disease and death."

II.—Pollution of the Soil by Interments.

The burial of human remains in the ground, a practice universally observed by Christian peoples, seems to be the most natural mode of the disposal of the dead. Whether it is the best plan from a sanitary point of view is a question which has, during recent years, excited a very general and thorough discussion. Various substitutes have been proposed, such as aquation or burial at sea, chemical destruction of the body, its preservation by embalming, and cremation. Burning the dead is the only innovation seriously proposed, and the advocates of the revival of this ancient custom have supported their arguments by the practical demonstration of the feasibility of the scheme. The experiments made by Dr. Polli, at Milan, by Prof. Gorini, at Lodi, by Prof. Brunetti, Sir Henry Thompson, Prof. Reclam, and others, show how quickly, thoroughly, and inoffensively the destruction of human remains can be effected by means of combustion.[2] The occasion for this discussion arises from the fact, that the present mode of disposing of the dead, by burial, is objectionable, on account of dangers to the public health. By the decomposition of

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[1] Sewage and Sewage Utilization, 1875, p. 127.

[2] The subject of the disposal of the dead is discussed in the chapter on Public Nuisances.

human remains the soil becomes polluted, and there is consequent contamination of the air and water. Hence persons living in the vicinity of grave-yards may suffer in their health by breathing vitiated air or from drinking impure water.

Where the population is scattered, danger to health from these sources is hardly to be apprehended; but where people are collected together in great masses, as in large cities, provision must necessarily be made for the disposition of a vast number of bodies, and if great care is not taken, the public health is apt to suffer from the effects of close proximity of crowded cemeteries to the abodes of the living.

In London, for example, where over 80,000 persons die annually, the proper disposal of the dead is a very serious question. Before interments in grounds within the city were forbidden, numerous instances occurred where the public health was affected by these pestiferous spots. As the population increases, grave-yards now suburban, unless very distantly located, will be encroached upon and the evils of intramural interment will again arise. This has happened in Philadelphia. Cemeteries which were formerly beyond the city limits are now surrounded by populous neighborhoods, and though their use is discouraged by the health authorities, it is not prohibited by law, and is, therefore, to some extent, still continued. While there is no danger of contamination of drinking-water—this being supplied by the public works—and while the air from these places is probably too much diluted to be injurious, there is a possibility of the health of persons living in the immediate proximity of the grave-yards suffering from the effects of noxious gases, which may be drawn into houses through the basement, especially in the winter season, when the air inside is artificially heated and has a suction power.

The processes of decomposition and decay commence soon after death, and are continued more or less rapidly according to climate, the nature of the soil, and the activity of certain lower organisms which prey upon the dead. These low forms of life are always richer where there is free access of air. A porous soil, through which there is an active change of air and water, hastens the return of the body to its natural elements. The products of decomposition are carbonic acid, carburetted and sulphuretted hydrogen, ammonia, nitrous and nitric acids, and various more complex gaseous compounds and offensive organic vapors, which are resolved into simpler combinations by the oxidizing power of the soil. The non-volatile substances remain in the ground, are taken up by the roots of plants, or are washed away by water passing through the pores of the soil. The osseous framework, which is the least destructible part of the body, relinquishes its animal constituents rather slowly, and, on account of its composition being largely of mineral substances, may resist disintegration for an unlimited period.[1]

Soils differ very much in the manner in which they effect these destructive changes. There are grounds in which a corpse may be completely

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[1] Parkes: Op. cit., p. 472.

destroyed in three or four years,[1] and others in which twenty-five or thirty years will be required for the effectual decomposition of the body. If there be a proper selection of the ground, with especial reference to the facility of constant change of air, and if its powers be not overtaxed, the powerful absorbent and oxidizing qualities of the soil, aided by the action of growing plants, may be depended on to dispose of, in a harmless manner, the gases and vapors evolved during decomposition. If, on the other hand, these precautions are not observed; if a soil be chosen in which there is stagnation of air and water; if the bodies are buried in close contact and with an insufficient covering of earth,—the offensive gases and putrid vapors evolved in the process of decomposition will accumulate and assume dangerous proportions. The ground becomes saturated with these foul products to such a degree as to be incapable of further absorbing them, and the air and water of the locality are poisoned by the noxious matters emitted from the surcharged soil. Such burial-grounds are an evil, no matter where located; but when situated in close proximity to dwellings, they are undoubtedly most detrimental to health.

The practice of interment in cities and towns in vaults, church-yards, and in small and confined spaces surrounded by habitations, has been observed until within comparatively recent times. The pernicious effects of this custom became so evident that its further continuance has been forbidden by legislative enactments. In Europe most of the governments have prohibited intramural interments absolutely. But in America the government has done nothing in this matter, the regulation of burial-grounds being controlled by municipal and State authority. The consequence is, that the change in this most insanitary practice has not been so general and thorough as might be desired. The improvement, however, has been very marked, and it is due not so much to stringent municipal or State regulation, as to private enterprise and enlightened public sentiment.

Spacious and attractive cemeteries situated beyond the city limits are rapidly superseding the old burial-grounds located in the midst of habitations. And as most of these rural burial-places are managed by private corporations, that have a pecuniary interest in their success, great care is exercised in the selection of the site, not only to avoid the encroachments of the population and future interference from this source, but also with respect to the natural fitness of the soil, the picturesqueness of the location, the object being to offer to the public a spot naturally attractive, adorned with trees and herbage, isolated yet easily accessible, and otherwise desirable on account of the care with which interments are conducted, the observance of strict sanitary regulations, and the general good management of the grounds. Such cemeteries are Mount Auburn, Laurel Hill, and Greenwood, which are celebrated throughout the country. These beautiful spots the traveller never visits without satisfaction.

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[2] Orfila and Lesueur, in experiments made to determine the time required for the destruction of bodies buried in the ground, found nothing but the skeletons after 14, 15, and 18 months; but this is very unusual.

But in many places the old, crowded intramural church-yards and burial-grounds are still in use. That this practice is attended with injury to the public health, there can be no doubt. The nearer places of sepulture are to the abodes of the living, the greater will be the dangers arising from contaminated air and water. The evidence on this point is incontestable. Mr. Chadwick says, in his able report on the Practice of Interment in Towns, "that, inasmuch as there appear to be no cases in which the emanations from human remains in an advanced stage of decomposition are not of a deleterious nature, so there is no case in which the liability to danger should be incurred, either by interment or by entombment in vaults, which is the most dangerous, amidst the dwellings of the living,—it being established, as a general conclusion, in respect to the physical circumstances of interment, from which no adequate grounds of exception have been established, that all interments in towns, where bodies decompose, contribute to the mass of atmospheric impurity, which is injurious to the public health."

In the same report he further remarks: "I have no doubt whatever that the burial-grounds, as at present constituted [intramural burial-grounds], are a continual source of pestilence, slow perhaps in its operation, and hence overlooked by ordinary observers. They are undermining the constitutional stamina of thousands of our town populations, while people are denying that they have any injurious tendency; and it is only when some epidemic comes to try it, like a touchstone, that the consequences of long antecedent neglect become so apparent as to rivet and excite alarm." . . . .

"The grave-yards of London are still the plague-spots of its population. The putrid drainage from them pollutes its wells, seethes beneath its dwellings, and poisons its atmosphere. Some parts of the metropolis are still honey-combed with deposits of the putrescent remains of millions of its citizens, just as with cesspools and other abominations. The vaults of many churches are still little better than charnel-houses, which it is absolutely dangerous to enter, or, if they have been ventilated, the noxious effluvia which they ceaselessly generate have been poured forth to contaminate the atmosphere without." These are some of the reasons which led to the final abolition of intramural interments in London and other English cities, and they are still applicable to all places where the practice is still continued.

Intramural interment was seldom practised in ancient times. The old Roman law forbade it. This law was occasionally infracted in the early days of Christianity, and at one time the privilege of burial within cities was accorded in special cases as a mark of distinction. Between the years 381 and 509 the law was again stringently enforced, with the object of preventing infection, and the remains of the dead which had been previously buried within the cities were directed to be removed. In this latter year, the first Christian cemetery was established in Rome. This was the commencement of the practice of burial in church-yards and small enclosed places within the inhabited parts of cities, which was continued, with occasional restrictions and modifications, until the eighteenth century, when the evils of the practice had become so monstrous that the governments of Europe, under the advice of learned men, began to enact laws prohibiting or restricting this mode of sepulture. Since that period the reform in this practice has been progressive.

In the latter part of the eighteenth century the grave-yards in Paris were closed, and rural cemeteries substituted for them. Subsequently the law was made more general. The disinterment of bodies in the old cemetery of the Innocents in Paris, in 1785, was directed on account of the sickliness of the neighborhood. So impure was the air in the adjoining cellars, that candles were quickly extinguished by it. Although the winter season had been selected, and every precaution was observed in conducting the work, a number of grave-diggers were suffocated on the spot by the escape of poisonous gases. After the removal of the remains, the neighborhood became healthy.

Typhus and other fevers were prevalent in the immediate locality of the London grave-yards, when it was a common practice to use the same grounds over and over again without any reference to the number of previous interments. The soil became saturated with the products of putrid remains, and the offensive effluvia arising from its surface were believed to be the cause of these fevers.

Dr. Allen mentions an instance where sickness was caused by breathing the vitiated air emitted from a grave-yard. In 1814, soldiers stationed near the Potter's-field, in New York, which was most offensive, were attacked with diarrhœa and fever. After removal,—which was promptly after the commencement of the sickness,—one of the sick died, and the others recovered. Dr. Barton is authority for the statement, that the yellow fever was greatly aggravated, in the epidemic of 1853, in New Orleans, by the exhalations from the overcrowded intramural tombs.[1] Norfolk and Portsmouth suffered in the same way during the memorable epidemic of yellow fever in 1855, which nearly depopulated those towns. Most of the interments were made within the towns, and under most unfavorable circumstances as to soil. The water-level was only six feet from the surface, and the graves were made about four feet deep, and frequently contained as many as two or three bodies.[1]

Dr. Rauch[1] attributes the spread of the cholera in the vicinity of a cemetery in Burlington, Iowa, in 1850, to effluvia generated by the decomposition of bodies recently buried. No cases occurred in this neighborhood until after twenty bodies had been interred, and, then, in the direction of the wind from the cemetery.

Dr. Reed detected the escape of deleterious miasma from graves twenty feet deep. He says: "In some church-yards I have noticed the ground to be absolutely saturated with carbonic-acid gas, so that whenever a deep grave was dug, it was filled, some hours afterward, with such an amount of carbonic-acid gas that workmen could not descend

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[1] **Rauch: Intramural Interments in Populous Cities, 1866.**

without danger. Deaths have indeed occurred in some church-yards from this cause."[1]

Mr. Walker, in "Gatherings from Church-yards," has given many cases, some of which were fatal, to show how malignant is the influence of crowded grave-yards in confined places.

In the early part of 1874 there was a great amount of sickness in the vicinity of the Battersea Cemetery, London, which, on account of the dangerous and alarming proportions it assumed, was made the subject of investigation. The general belief that the sickness was caused by emanations from the crowded cemetery, though not positively confirmed, was not disproved by the investigation.[2] Numerous other instances might be given to show the injurious effects of breathing the air of burial-grounds.

The gases and offensive organic matters given off from bodies during the process of decomposition are found in the air of vaults in concentrated form, and can be traced in the air of church-yards. According to Parkes, "the air of church-yards is richer in carbonic acid (.7 to .9 per 1,000: Ramon da Luna), and the organic matter is perceptibly large when tested by potassium permanganate. In vaults, the air contains much carbonic acid, carbonate or sulphide of ammonium, nitrogen, hydrosulphuric acid, and organic matter. Fungi and germs of infusoria abound."

The influence of these emanations on health is manifest in proportion to the degree of concentration. It is evident that, in very concentrated form, they may cause asphyxia[3] and sudden and complete extinction of life. In less concentrated form, the result may be a depression of the vital powers, and a disturbance of the healthy functions of the system. If these effects are often repeated and the putrefactive emanations long applied, they may produce fevers,[3] or impart to fevers due to other causes a typhoid or low putrid character. Contagious material may also be present in the effluvia from dead bodies. The putrefactive exhalations may cause the most developed form of typhus fever.[4]

The contamination of drinking-water is sometimes caused by the too close proximity of burial-grounds to the sources of supply (wells and rivers).

Professor Brande mentions an instance of a well near a church-yard, "the water of which had not only acquired odor, but color from the soil;" and he is of the opinion, that the superficial springs adjacent to burial-grounds must be more or less affected by the products of decomposing bodies accumulated in the soil.

Eassie states, that during the Peninsular war the English troops suffered greatly from low fevers and dysentery, caused by being obliged to

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[1] Bulletin of Med. Sciences, Philadelphia, 1845, p. 135.

[2] Med. Times and Gazette, Nov., 1874, p. 579.

[3] Tardieu: Dict. d'hygiène, 1862, T. III., p. 463 et seq.

[4] Dr. Riecke's Report on the Influence of Putrefactive Emanations on Health, quoted by Chadwick: The Practice of Interment in Towns, Philadelphia, 1845.

drink water drawn from wells located close to grounds in which the bodies of their deceased comrades had been buried.[1]

Another instance of water-contamination is that reported by Dr. De Pietra Santa, as having occurred at the villages of Rotondella and Bollita, in Italy. The cemeteries of these villages were located upon the summit of a wooded height at a considerable distance from the houses. The springs from which the water-supply was obtained were at the foot of the hill, and as they were fed by water which had filtered through soil polluted by decomposing bodies, they became highly contaminated, and eventually caused a severe epidemic.[2]

A similar case occurred recently in Barbary, at a time when the plague prevailed. The inhabitants of a small village, who lived in excavations in the rocks, obtained their water-supply from wells which received the drainage of a cemetery where bodies were covered with gravel only one foot in depth. Those only who drank of this polluted water suffered from the plague.[3] Rheinhard relates, that, during the prevalence of the cattle-plague, in Dresden, a number of victims were buried at a depth of ten or twelve feet, and, during the following year, it was found "that the water from a well situate one hundred feet from the pit in which they were buried had a fetid odor and contained butyrate of lime. At a distance of twenty feet, it had the disgusting taste of butyric acid, and each quart contained about thirty grains of this substance. The bodies were subsequently disinterred and burned."[4]

Recent investigations, made by Prof. Fleck, into the condition of the well-water in the cemeteries of Dresden, show that, with one or two exceptions, it contains a large amount of organic matter.[5] This is particularly the case in the well-waters of three of the oldest cemeteries, "where, besides notable quantities of nitrates, there was found a very considerable amount of unoxidized organic matter."[6] It is remarked that "the composition of the cemetery-water does not differ essentially from that of the average well-water in Dresden in respect to the decomposing organic matter;" but this is constantly exposed to the danger of contamination from decomposing and putrefying organic substances escaping from cesspools and privy-vaults, and from drain-pipes and sewers, and is more or less impure. That injurious effects have not been observed to follow the limited use of the cemetery-water by the grave-diggers and their families, does not justify a conclusion that such waters are safe to drink. The water of wells located in grave-yards, or in close proximity to grave-

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[1] Cremation of the Dead, London, 1875, p. 62.

[2] Eassie: Op. cit., p. 64.

[3] Adams: Cremation and Burial, Sixth Annual Report of Mass. State Board of Health, 1875, p. 279.

[4] Chicago Med. Examiner, Aug. 1, 1874.

[5] The exceptions are the water from the Trinity and Elias cemeteries, which are situated in clean coarse gravel.

[6] Adams: Loc. cit., p. 282.

yards, should always be looked upon with suspicion, and its use prohibited.[1]

Abandoned burial-grounds[2] should not be disturbed for the purpose of removing the bodies, until the lapse of a number of years after the last interment has taken place. Bodies decay in very various times, and therefore the proper period at which to perform this work cannot be definitely fixed. Wherever undertaken, proper precautions should be observed. In no case should a general disinterment of bodies take place in warm weather. It would be better if disused grave-yards were converted into parks, and planted with rapidly growing trees and herbage to absorb the organic substances contained in the soil.

Cemeteries should be located at convenient distances from towns. In selecting the site, particular attention should be given to the character of the soil. This should be dry, well-aërated and well-drained; the ground-water should never reach the lowest grave, nor rise into the vaults. The drainage should never have access to wells or rivers from which drinking-water is taken. Rapidly growing trees and shrubs should be planted. It would be a wise precaution to surround every cemetery with a belt of trees, as suggested by Dr. Adams, to act as a barrier to the escape of deleterious miasmata. If there be a choice, a porous, coarse-grained gravelly soil, or a light marly soil, should be selected. In all cases it should allow of a free movement of air and water through its pores and interspaces. A vegetable mould covering the formation will assist in neutralizing the noxious exhalations, and will favor the growth of plants. Lime and chalk soils have advantages. Stiff marly soils, and especially stiff clays, preserve bodies for a long time, and hence they are to be avoided if possible. The selection of a declivity has the advantage of facilitating the drainage of the ground. Underground drainage will be necessary where the soil is damp. In all well-regulated cemeteries this is always resorted to as a means of securing a proper condition of the surface of the ground, and of insuring a dry state of the subsoil.

Bodies should always be buried at a depth of at least six feet from the surface of the ground to prevent air-contamination, though, if nearer the surface, the decomposition would be more rapid. But one body should be buried in a grave at one time, and the same grave should not be used a second time, until after the complete decomposition of the body previously interred has taken place. The graves should not be walled up, but the earth should come in direct contact with the coffin. Mr. Haden has called attention to the advantages of perishable coffins, such as might be formed from wicker-work, the object being to let the earth come in contact

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[1] The water from grave-yards contains "ammonium and calcium nitrites and nitrates, and sometimes fatty acids, and much organic matter. Lefort found a well of water at St. Didier, more than 330 feet from a cemetery, to be highly contaminated with ammoniacal salts, and an organic matter which was left on evaporation. The water was clear at first, but had a vapid taste, and speedily became putrid." Parkes: Op. cit., p. 25.

[2] Tardieu: Dict. d'hygiène, 1862, T. III., p. 463 et seq.

with the body as speedily as possible, so as to hasten the putrefactive changes.

Houses used as habitations should be at least 500 yards distant from any cemetery, to prevent the influence of contaminated air. The greatest caution should be had with regard to the water-supply. It should never be taken from a well situated in a cemetery or close to one. In this connection great care should be taken of the drainage.

In "air-tight" vaults the process of decay is slow, and the escape of gases is likewise slow, and hence there is less danger of pollution of soil, air, and water, when this plan of disposal is adopted. This method, however, will never be practised to any great extent, as it is too expensive; nor is it desirable that it should.

Various means have been made use of to prevent offensive decomposition. Quicklime is sometimes used, but charcoal is preferable, as its powerful absorbent and oxidizing qualities prevent, in a measure, putrefaction and the evolution of foul-smelling gases. In special cases this substance may be heaped in graves; and, if not procurable, a good substitute will be found in sawdust and sulphate of zinc, or carbolic acid. (Parkes.)

Lime, charcoal, and sulphate of iron were used to disinfect the graves of men, horses, and cattle, around the town of Metz. Grain was sown wherever practicable, and the mounds over the trenches were planted with trees. Bodies which had been superficially buried were disinterred with the greatest precaution, disinfectants being applied to the whole earth around each body before its removal.

Louis Creteur, to whom was entrusted the work of disinfecting the dead-pits near Sedan, made use of nitric acid, sulphate of iron, chloride of lime, and chlorine gas, with satisfactory results. Carbolic acid proved to be less efficacious.

Baron Larrey recommends the use of deep-dug ditches—in permeable soil, if it can be selected—and the free use of quicklime, which will give rise to slow combustion. The lime will absorb the carbonic acid and convert the sulphur and sulphuretted hydrogen into sulphuret of calcium. It is very important that the lime should be freely strewn upon the bodies, and that they be covered with a deep layer of earth to absorb impure emanations.

Cremation has been advocated as the safest mode of disposal of the dead in war, and Mr. Eassie has recommended the use of "ambulatory furnaces" for this purpose.

When the number of interments is excessive, especially in times of epidemic, the same precautions must be observed as indicated above. The liberal use of disinfectants will be required, and even more than usual care should be taken in the final disposition of the bodies, that they shall at no time thereafter exert a malign influence.

Cemeteries should be regulated by State laws, which ought to include a provision for minute and active supervision. It might be a part of the duty of State boards of health to receive periodical reports of the sanitary condition of all burial-places, and of the manner in which they are regulated. The exact condition of every such place would be a matter of record, and among the advantages resulting from this plan of central supervision would be the prevention of overcrowding and the continued infringement of any of the regulations.

III.—Pollution of the Soil by Coal-gas.

The pollution of the soil by coal-gas is not an infrequent occurrence in large towns, where miles upon miles of gas-pipes are laid beneath the surface of the streets, in which position they are exposed to the risk of fracture or of injury to their joints from various causes.[1] The metal may be weakened by corrosion, and give way under too great super-imposed weight. This is a rare accident, and, when it does happen, it is quickly discovered. Leakage at the joints is, however, a more common occurrence, and it is often a difficult matter to detect the precise point at which the escape of gas takes place. Gas-pipes are sometimes exposed in making excavations for building new sewers or for repairing old ones, and, if not properly supported, they may be strained at their joints by the subsequent subsidence of the earth carelessly thrown into the trenches. However produced, a leak in the gas-main or connecting-pipe, even though it be a small one, will speedily result in impregnating the soil with a most deleterious compound, which exerts its injurious influence upon the human system through the medium of well-water or by poisoning the air of dwellings.

The gas may pass into the sewers, and be drawn into houses through trapless or badly trapped drain-pipes. Its escape at the street-surface or at the sewer-openings may cause annoyance by the unpleasant odor ; but dilution by atmospheric air lessens its hurtful influence. The more common and most dangerous channel of entrance into houses is by the pores of the soil under the basement-floors. This is more liable to occur in the winter season, for reasons which will be explained. Ill health and even death has been caused by coal-gas escaping into houses in this manner.

All soils are porous and contain air in more or less active circulation. The "ground-air," as it has been called, is in continual intercourse with our houses. Whenever the air inside is warmer than the external air, an upward current will be established through the foundations. Heated houses, therefore, "ventilate themselves not only through the walls, but also through the ground on which the house stands." The penetration of coal-gas into houses is thus aided by the upward current of the "ground-air," caused by the heated house. The suction-power created by the fires

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[1] The soil in which pipes containing illuminating gas are embedded has often a powerful odor of it, and is frequently much discolored. This is, without doubt, partly occasioned by loss through the walls of the pipes, to guard against which, so far as is practicable, gas companies test their pipes by subjecting them to a powerful pressure. Fox: San. Examinations of Water, Air, and Food, 1878, p. 213.

within doors in the winter will serve as an explanation of the fact that these accidents from coal-gas have happened only at that season of the year. This latter circumstance has been made use of to prove that the frozen soil does not allow the gas to escape in an upward direction, but diverts it in another direction. But this is a mistaken idea, as the frozen soil is not more air-tight than when not frozen. (Pettenkofer.)

A number of instances are on record where persons have been fatally poisoned by the entrance of gas through the foundation-floors. Says Prof. Pettenkofer: "I know cases where persons were poisoned and killed by gas, which had to travel for twenty feet under the street, and then through the foundations, cellar-vaults, and flooring of the ground-floor rooms." In one of these cases there was not the least smell of gas noticeable in the street, the gas being diverted with the current of ground-air toward the house. In another case the gas always found its way into the best heated room and produced an illness of its inmates, which was at first thought to be typhoid fever. Dr. De Chaumont has reported an instance, in his own observation, of fatal poisoning by coal-gas, which gained admission to the house through the foundations.

Dr. Emil Rochelt has reported[1] a recent case of poisoning by coal-gas, which occurred in Innsbruck, in March, 1875. Three persons, a man, his wife, and daughter, were poisoned in the night, the latter two fatally, by the escape of illuminating gas from a leak in the street-pipe, which had from some cause or other become broken. As the ground was frozen and covered with snow, the escaping gas could not find a passage upward through the street surface; it therefore forced its way horizontally through the less-resisting earth (?) into the house and into the rooms, where these persons were lying unconscious of its presence. Passers-by, noticing the smell of gas and seeing the house closed, which was unusual at this hour of the day (8½ A.M.), broke open the door and found the wife and daughter dead, and the man in a cyanotic condition. From the effects of the poison he made a very slow recovery, but with impaired mind.[2]

Drinking-water is sometimes contaminated by coal-gas, which finds its way into wells and water-mains from the impregnated soil. This latter case is rather rare. It is more likely to occur when the water-supply is intermittent. Parkes says, that in Berlin, in 1864, out of 940 public wells, 39 were contaminated by admixture with coal-gas. An instance is mentioned by Mr. Harvey where coal-gas entered the water-mains, which were often only filled with air.[3] Coal-gas, in limited quantity in water, is not easily detected, but by warming the water to 110° F. it will be perceptible to the smell. (Tiemann.)

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[1] Wien. med. Presse, XVI., 49, 1875.

[2] The cause of the direction taken by the liberated gas does not depend so much upon the frozen condition of the ground as upon the aspiratory power of the heated air of the house, which has the effect of establishing a current in the surrounding "ground-air" toward the house. Any gas in the "ground-air" will enter this current.

[3] Harvey: Food, Water, and Air, February, 1872, p. 68; and Parkes: Op. cit., p. 28.

Coal-gas sometimes finds its way into sewers, and thence into houses through the channel of the communicating drain. Serious explosions have been known to occur from the accumulation of large volumes of gas in the sewers. An instance of this kind occurred in Philadelphia several years ago. A sewer near the gas-works became filled with gas from a leak in a neighboring pipe. The strong odor of gas had been noticed, but it was supposed to have come from the adjoining works. From some cause unexplained, the gas exploded with terrific noise, rending the sewer and tearing up the street for a considerable distance, but fortunately with no loss of life.

The means of preventing the pollution of the soil by coal-gas are, primarily, the selection of the best material for the pipes and joints, the employment of skilled workmen, and the careful supervision of the work of laying and joining the pipes by engineers of ability; and, secondarily, the provision of means of access to the pipes, so that they may be inspected at frequent intervals without tearing up the street. Subways for the pipes might be constructed. By their use, a leak could be easily detected, and the expense and inconvenience of tearing up the streets, which is often a fruitless operation, would be avoided.

IV.—Pollution of the Soil by Surface Defilement.

The presence of foul refuse-matters, solid and liquid, upon the surface is another source of soil-pollution. Slovenliness and neglect in the removal of putrescent refuse-matters, which are the product of every-day life, are the cause of nuisances which afflict most communities. The waste materials produced by the activities of domestic life, offal from kitchens, house-slops, the dung and urine of animals, and even human excreta, sometimes lie exposed upon the surface or are stored in receptacles, undergoing decomposition, and causing a nuisance by offensive exhalation or by soakage into the ground. From these sources the surrounding air becomes contaminated and the soil polluted. As the result of the infiltration of the soil with the liquid parts of refuse, there is often pollution of the water of wells and springs and of the air of houses.

House-slops, including kitchen-water, if not disposed of promptly, or if allowed to flow over the surface, will speedily give rise to a nuisance. Where sewers exist, these liquids may be gotten rid of by means of underground pipes connected with the sewer, and in small places by adopting a plan similar to Field's flush-tank system. Chamber-slops may be disposed of in the same way, or, where the earth-closet system is in use, by the means provided by that system. These liquids should never be allowed to flow over the surface or in open channels or public gutters.

Kitchen-garbage or kitchen-waste—that is, the animal and vegetable substances discarded in the preparation of food—and the waste bits from the table, if not immediately utilized or burned in the furnace or kitchen fire, should be placed in small receptacles made of non-absorbing material. These receptacles should only be large enough to hold the accumulations of one or two days at the most. This kind of refuse rapidly decomposes, and, therefore, in order that no nuisance arise, it is of first importance that the removal should be regular and frequent. In summer time, the daily removal will be required. But in the winter season, every other day may suffice. In populous places, the removal must take place under the direction of the local authority. The so-called dry-refuse of houses is a very heterogeneous mixture. It is principally composed of ashes, house-sweepings, rubbish, and bits of animal and vegetable matter. It may contain, and often does contain, kitchen-garbage, and even liquid and solid excreta. The addition of these substances gives an extremely offensive character to the refuse. Among certain classes of the population it is found impossible, in practice, to prevent this breach of sanitary propriety, and, therefore, the regulations relating to the removal of house-refuse in towns must be framed purposely to meet this defect in domestic management. A daily removal of this material may be required in some cases—in fact, will be absolutely necessary, to prevent it from becoming highly offensive. When the refuse-receptacle is used for its legitimate purposes, and is properly managed, a bi-weekly or even weekly removal of its contents will fulfil all the requirements of cleanliness and decency.

House-slops should never be thrown into the rubbish-receptacle, and the latter should be protected from rain by a proper covering, as the admixture of liquids with refuse tends to promote decomposition, and the formation of offensive odors. A movable receptacle should always be preferred for convenience in cleansing and in handling. It may be made of galvanized iron, or of wood coated with non-absorbent material. It should not be unnecessarily large, being restricted in size to a capacity for accumulations of a very limited period. A half petroleum-barrel will form a very convenient ash-tub for general use in populous districts.

The storage of refuse on the premises should be avoided, if possible, as the practice, if not regulated with the greatest care, is liable to cause a nuisance by the production of effluvia and by soakage of offensive liquids into the ground. If a fixed dust-bin be used, it should be well made of impermeable material, to prevent soakage, well-covered so as to be kept dry, and well-located so as to be convenient of access, both for the house and for the removal of its contents by the scavenger. In small places the dry refuse may be disposed of advantageously by burning, but in towns there is not space sufficient for this mode of disposal, and the smoke and smell created by the act would cause a serious annoyance. In such places its eventual utilization lies within the domain of the authorities. It is generally carted outside the town, where it is picked over and sorted, and the discarded portions used for "filling in."

The various kinds of trades and businesses which give rise to animal or vegetable refuse, may contribute to the defilement of the surface and to the pollution of the soil by soakage. The want of proper receptacles for these waste matters, the neglect of their prompt removal, and the absence of underground drainage, lead to the soakage of the putrescent liquid substances, both within and beyond the premises, and thereby cause an offensive nuisance. Places for the slaughtering of cattle frequently give rise to these evils. The washings mixed with blood and particles of animal matter, and the oozings from badly-kept manure-heaps, so common about slaughter-houses, when exposed upon the surface or imbibed by the soil, rapidly undergo decomposition and give off deleterious products. Businesses which handle all sorts of animal and vegetable substances, such as bone-boiling, fat-rendering, meat-packing, vegetable-canning establishments, and the like, always require the most particular attention, in order to prevent the insanitary disposition of the putrescent refuse.

Market-houses also require careful supervision, as these places are liable to cause a nuisance by accumulating refuse, and by careless disposal of surface-washings.

The keeping of horses and cattle in populous places, unless care is taken to have the floors of the enclosures paved with impermeable material and well drained, the temporary receptacles for refuse well-cemented and frequently cleaned out, and the liquid refuse conducted away by proper underground conduits, will create a nuisance by soakage within the premises, or defilement of the surface beyond their limits by the offensive outflow. It is needless to further enlarge upon this subject, as it has been treated elsewhere in the chapter on Public Nuisances, under the head of Offensive Trades.

The deposit of refuse-matter upon the surface of the public ways, if not promptly removed, will give rise to the contamination of the air by the decomposition of the organic substances of which it is largely composed, and to the pollution of the soil beneath the pavements by soakage of liquid impurities. This is more apparent when we inquire into the composition of street-dirt. In addition to the inorganic detritus of the road, it consists of the dung and urine of horses, and sometimes of cattle, of vegetable matter from trees, of refuse from houses, sweepings from yards, kitchen-garbage, kitchen-water, and house-slops, containing animal and vegetable matter, and, in poorer neighborhoods, these are sometimes mixed even with human excrement, both solid and liquid. This mixture of animal and vegetable substances, when wetted by rain, soon decomposes on exposure to the heat of the sun, and develops foul effluvia which must be detrimental to health, especially in crowded and ill-ventilated localities. And further, unless the pavement is composed of impervious materials, the liquid filth penetrates the surface and soaks into the soil, and from this storehouse of putrescible matter, the water of wells is exposed to the danger of pollution, and the air of houses to contamination through the medium of intercourse with the "ground-air." These evils depend upon imperfect drainage, a bad system of scavenging and refuse-removal, and, very materially, upon badly constructed pavements. The fundamental fault lies in the defectiveness of the street-pavement. Inequality of surface favors accumulations, and thwarts the best-directed effort at cleansing. Gutters are often unevenly laid, so that stagnant pools of water are always present. This fault is especially glaring where the practice of draining house-slops on the public ways is permitted.

The sanitary importance of a thorough cleansing of the public ways is plainly to be seen. And this cannot be accomplished without the provision of a suitable surface—such an one as will prevent the retention of filth, and the penetration of its liquid portions downward into the soil. It is especially important that this provision should be extended to all small streets, courts, alley-ways, and all crowded and badly ventilated localities, where the poor are packed together, as it is in such places that the street is apt to be used as a common receptacle for all sorts of refuse-matter; and it is therefore all the more necessary that such a surface shall be furnished as will prevent the retention and imbibition of filth.

Street-Pavements.

At the present day street-pavements are included among the more important sanitary works, and properly so, since it is an essential condition of public health, that all town roadways, of whatever description, should be well drained, non-retentive of filth, and as noiseless as possible. A thoroughly well-paved town, other things being equal, must of necessity have a lower death-rate than one with the opposite condition of its streets and alleys. Evidence could be cited confirmatory of this statement.

In the construction of street-pavements, it is of primary importance that every sanitary advantage should be secured. Until recently this phase of the subject has been pretty generally ignored. The question of the kind of pavement best adapted for ordinary traffic, and best suited to meet the requirements of public hygiene, is not so easily determined. The principal kinds, at present in use, are the cobble-stone, the macadamized, the granite-block, the wood, and the asphalt pavement. The two last are probably preferable, from a sanitary standpoint.

The cobble-stone pavement has been much used in the United States. The stones being easily procurable from the gravel of the diluvium, or along the sea-shore or river-beaches, have been very generally resorted to as an economical and durable material for covering street-surfaces. If stones of the harder variety, and of nearly equal size, are selected, and if they are closely set and well laid upon a good bed of gravel and sand, they make a cheap and substantial pavement, which affords a secure footing to horses, and has the advantage of being easily repaired. But there are serious objections to this kind of pavement, from a sanitary point of view. The most prominent of these arises from the fact that it is the most difficult pavement to keep clean. From the shape of the stones it is impossible to fit them to each other so as to form a perfectly smooth surface; and, therefore, the spaces left between them, at first covered up with clean gravel, soon become filled with filth, which it is found impracticable to remove. Through these interstices the liquid filth permeates the underlying earth, so that in time the bed of the street becomes saturated with impurities in the most concentrated form. Every one is, perhaps, familiar with the very offensive black earth uncovered by the removal of an old and worn-out cobble-stone pavement. The effluvia arising from the surface of this filth-sodden soil exert a baneful influence upon the health of those who are compelled to breathe an atmosphere thus vitiated with impurities. Particularly is this the case in narrow, crowded streets, where the evil is intensified by the want of proper ventilation.

Another objection to this kind of pavement—and in fact to most stone pavements—is the noise created by the rattling of vehicles over the rough surface. To persons in sound health and of strong constitution, it may be a matter of trivial concern; they become accustomed to it, and, apparently, in no wise suffer from its effects. But to persons of a delicate, nervous temperament, and to the sick, this nuisance is particularly distressing. The tan-covered pavement tells the tale of the aggravated and intolerable suffering to which the sick have been subjected. The incessant din of constant traffic is bad enough in the daytime; but when it is prolonged into the hours commonly allotted for rest, it interferes with the healthy condition of sleep. The constant noise by day, and the interference with sleep at night, annoy the nervous system, and tend to render it morbid.

The macadamized roadway has certain well-recognized advantages, such as smooth surface, comparative noiselessness, and compactness of structure; but it is by no means suitable for the public ways of a large town. It soon becomes ground into fine mud, which is composed of finely pulverized stone mixed with horse-dung, sand, and other materials. In moderately wet weather it is converted into a slush, which coats the surface, rendering it very slippery, and otherwise objectionable. By heavy rains this mud is washed into the sewers, which it obstructs, and into the rivers, where it renders heavy dredging operations necessary. "The deposit of detritus of the roads of London in the Thames will cause a serious and irreparable injury to the port of London, which no amount of dredging will be able altogether to remove after some more years of continuance." (Denton.) This is largely due to the wear of macadamized roads. Very active dredging is required to prevent the blocking up of the Seine by such detritus at the mouths of the outfall-sewers. About 150,000 tons of solid matter are annually discharged into the Seine from these sewers. In 1874 about 180,000 francs were expended for dredging operations near the sewer-outlets.

In dry weather the mud upon the streets becomes converted into dust, which is wafted about in every direction to the annoyance of the people, and possibly to the injury of their health. Other objections are the expense of construction and repairs, and of frequent sprinkling to allay the dust, and the great difficulty of keeping the surface clean.

Granite-block pavements also become pulverized under heavy traffic, but to a less extent. They are open to the objection that their interstices collect filth which it is impossible to remove, even by the best managed plan of cleansing. "The cubical stone blocks are displaced under the prodigious traffic, the corners and edges are worn away, the surface gets to be irregular, the joints are widened. The filth of the streets gathers in ruts and joints, is recruited constantly by new accessions of urine, horse-dung, and silt, and, diluted by rain, it ferments, and forms a putrescent organic mire, becoming, in course of time, a source of noxious miasmas. In hot and dry weather these nauseating deposits pass into the atmosphere in the form of unhealthy vapors, or, pulverized and drifted by the wind, cause inconvenience and poison our lungs. Indeed, in repairing old pavements, a black layer of ground, saturated with sulphuretted hydrogen, is found below the stone blocks, and bears witness to the infection of the subsoil by the soakage of contaminated water. Prof. Tyndall has established by experiments that a large proportion of the particles of dust in the rooms of London houses is of organic origin, and other experiments have demonstrated that horse-manure, in a state of decomposition, is a permanent ingredient.

"Vapors still more noxious than those from the road-bed of the streets rise from the gutters, the subsoil of which is saturated to a considerable depth by more concentrated matter of the described composition, and also from the surface of alleys on which are the houses of great numbers of people of limited means. Crowds of dirty children, whose tender lungs breathe the air immediately over this miasmatic soil, here contract constitutional predispositions, which doom them to a languishing and miserable life, and render them an easy prey to epidemics. This infection of the subsoil has been prevented, with a certain degree of success, by foundations of concrete. There is still another feature of stone pavements in the heart of cities, which affects the inner man more than the physical frame, viz., the rattling and noise, under heavy traffic, accompanied, in alluvial soil, by vibrations of the adjoining houses. People with strong nerves, and accustomed to this rattle from early youth, may, to some extent, become hardened, but they will never get to be insensible to it; any indisposition is aggravated by the nuisance, and for recovery they hurry to the country. People with weak nerves, especially delicately organized women, suffer great and permanent injury to the health. Nothing but the constant torment has partially dulled us to this evil. If cities had never been afflicted with this noise, and if, in a competition with other more suitable materials, stone pavements were adopted, a storm of opposition would soon sweep them out of existence again. Some of these difficulties have been obviated by using smaller and harder stones; but the objection to the improved Belgian pavement in general use, on account of the germs of disease stored in the wide joints and under the blocks, still remains."[1]

The wooden pavement has been brought forward within recent years as a substitute for cobble stones and granite blocks. It is claimed for it that it meets the objections encountered in stone pavements. It has been extensively used in the United States, and at one time stood in good repute, but it has been generally abandoned, the main reason for its disuse being on account of its tendency to decay. In England there has been a

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[1] Cluss: Modern Street Pavements, The Pop. Science Monthly, 1875, p. 82.

sharp contest between various kinds of pavements, particularly those made of granite, asphalt, and wood, which has been decided, after a prolonged comparative trial, in favor of the last; and the corporation of London has confirmed the decision and recommended the adoption of this style of pavement for the thoroughfares of that great city. Mr. Haywood, the engineer and surveyor to the commissioners of sewers of the city, has shown that horses travelling on the wooden pavement are, on the whole, liable to falls of a character less inconvenient to the general traffic in the street, and also less likely to be injurious to the horses than those which occur from travelling on the other pavements. The wooden pavement is rather more expensive than the asphalt, but this is counterbalanced in other ways. "In easy traction and the absence of noise there is no comparison between wood and granite, and since the surface-water has been kept out by means of asphalt, wood has become one of the most durable of pavements. The rapidity with which it can be laid, and the ease with which it can be repaired are not the least of its merits, while the flooring of planks, which is now laid as a substructure, gives great elasticity, and by distributing the weight equally over the whole pavement adds to its power of endurance."[1]

Although this experience does not correspond with the results of extended experiments made in this country, particularly as to the quality of durability, the disagreement may be explained by the fact, that an improved preliminary treatment of the material and a better plan of constructing the pavement, have overcome the defects which caused it to be generally discarded in the United States. If the proper kind and quality of wood be selected, and the blocks and foundation boards be thoroughly kyanized and boiled in asphalt until the material becomes completely saturated, and if a solid and impervious foundation of concrete be first laid, this pavement will undoubtedly be rendered very durable. This quality, in addition to those of smoothness of surface, noiselessness, and impermeability to moisture, will supply the essential conditions of a pavement considered satisfactory from a sanitary standpoint.

The asphalt pavement, when properly made, is probably the very best pavement that has ever been devised. It is smooth, noiseless, advantageous for traction, thoroughly impervious to moisture, and is very durable. It prevents the soakage of filth into the subsoil; it has no cracks or crevices to harbor impurities, nor unevenness of surface to retain waste matter and retard drainage. It is easily washed, and this is an important advantage for a pavement in alleys and courts where the application of the hose is often required. It is elastic in summer without being soft, and hard in winter without being brittle. "Not affording any escape to the terrestrial heat through joints, they [the pavements] are kept warm and open from below in most cases when block-pavements present an icy surface. Their smooth, seamless face, being almost entirely free from abrasion by attrition or atmospheric action, meets the mechanical and

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[1] The Year-book of Facts in Science and the Arts, 1876, p. 195.

hygienic objections to block pavements, both of stone and wood, as well as of macadamized roads. The asphaltum pavement is clean, and fit for traffic a few hours after being laid, while new or repaired stone roadways must be covered for months with heavy layers of sand, to be drifted by the breeze in dry weather and added to the mud in rainy spells. Repairs can be made to the asphaltum pavement in dry days of a cold winter, while with stone pavements any defects must be endured until spring. . . . The popularity of this pavement in the two largest cities of Europe, where, with immense traffic and most extensive experience on the relative value of pavements, the demands on the municipal authorities are inexorable, serves as a proof that smoothness of surface does not cause any danger with this material."[1]

The kind of pavement here alluded to is made of the mineral asphaltum, a porous limestone found in the Val de Travers, Switzerland, and known as the Seyssel or Neufchâtel asphaltic rock. It is a very different thing from the asphalt concrete which is made by mixing bitumen with sand, cinders, coarse gravel, or broken stones. These concrete pavements, as at first made, were a complete failure, their composition being such as would not withstand the influence of the heat of summer. During this season of the year they become soft and sticky, and hence the name "poultice" pavement. A great improvement, however, has been made in this kind of pavement, so that now a very good article can be procured at comparatively small cost, which is especially applicable to back-courts, alley-ways, and small streets upon which the traffic is light. It is quite durable, non-absorbent, and can be cleansed with the least difficulty.

A great many kinds of patent concrete pavements have been introduced in the United States, and as most of them were worthless, the reputation of the genuine asphalt pavement has suffered in consequence.

The asphaltic rock is a native limestone, composed of pure carbonate of lime in combination with more or less tough bitumen. The Tyrimont-Seyssel rock contains from 6 to 8 per cent. of bitumen, and that known as the Neufchâtel asphalt as much as from 11 to 12 per cent., a proportion considered very favorable.

"When the rock is heated to near 300° F., it crumbles into a mass of brown powder, which, when compressed in a mould and allowed to cool, recovers its original hardness and appearance. If the hot powder, instead of being placed in a mould, be spread about two inches thick on a hard foundation, and pressed or packed by a hard pestle or roller, and allowed to cool, the surface will immediately solidify, forming a crust identical with the original rock." The foundation should be a substantial one, made of ordinary concrete, which is composed of crushed stone and cement. It should be perfectly dry before the hot powdered rock is placed upon it.

A fair substitute is made by mixing Grahamite, a solid hydrocarbon, found in West Virginia, with the so-called Trinidad asphalt, and combining this compound with calcareous sand or carbonate of lime. This sub-

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[1] Cluss: Loc. cit., p. 87.

stitute for the Seyssel or Neufchâtel rock is greatly inferior to it, but it has advantages which will make it serviceable for roadways, provided it is always placed upon a good concrete foundation capable of resisting the pressure of heavy vehicles.

The waste-waters from houses are frequently discharged into the street-gutters, and left there to create a nuisance or to find their way into the nearest sewer-opening. This liquid refuse is composed of animal and vegetable substances, which rapidly putrefy under favorable circumstances. In courts and back streets, where the dwellings are frequently unprovided with underground drainage, chamber-slops often form an ingredient of this mixture. Says Dr. Simon: "Such refuse, at its worst, is a very condensed form of sewage, and, even at its best, is such as cannot, without nuisance, be let loiter and soak by the wayside." It is therefore of the highest importance that street-gutters should be constructed with a view of providing rapid and thorough drainage, and be made of impervious material, so that during the passage of the liquid filth or the obstruction of its flow, not a particle of it shall soak into the underlying soil.

Street inlets should be placed at frequent intervals to carry off the rainfall and surface-drainage before any accumulation can take place. These openings to the sewers should be provided with catch-basins to intercept mud and road detritus, which must otherwise pass into the sewer and cause obstructions. The inlets should be trapped with a good water-seal, and their mouths should be protected with a substantial iron grating, to prevent the entrance of any foreign substances other than those suspended or held in solution in the surface-water.

Street Cleaning, etc.

The cleansing of the public ways has an importance which cannot be too highly estimated. It affects the comfort of every individual, and exercises an important influence upon the public health.

The work of street-cleaning is performed either by contract under the direction and supervision of the town officials, or by persons in the direct employ of the local government, in which case it is conducted as a special service or department, the "plant," horses, storehouses, etc., being the property of the town. Both plans may be united, as is the case in Paris, where the removal of the dirt and the furnishing of the horses and drivers for the sweeping-machines are stipulated for under contract, and the rest of the work is done by the department itself. Either of these latter plans is to be preferred to the contract system, as experience has proved that they insure more thorough and reliable work. They may appear to be more expensive, but this can hardly be the case if the amount and quality of the work are taken into consideration. The city ought to save the profits of the contractors. An honest, rigid, and intelligent conduct of the work ought to secure economy, besides other advantages.

All the public ways should be maintained in a *thoroughly* clean condition at all times. To this end a daily cleansing may be necessary, especially in localities teeming with population or where traffic is heavy. In less populated localities, and in parts of the town where the streets are not much used, a less frequent cleansing may suffice. This must be determined by local circumstances.

The time at which the work should be performed will also be influenced by conditions of place. In large towns a certain portion of the work should be done outside of the ordinary business hours of the day. In all localities where the streets are occupied by traffic and are much frequented by the inhabitants, not only the comfort of citizens, but also the necessities of the case demand that all cleansing operations shall not be commenced until the daily activities have ceased, and that they shall be completed early in the morning, not later than 9 o'clock. In Paris, under the new *régime*, the general sweeping of the entire city is effected between the hours of 3 A.M. and 6 A.M. in the summer, and between 4 A.M. and 7 A.M. in winter. The wagons for removing the products of the sweeping, and for collecting the household refuse, are brought upon the ground at the termination of the sweeping, and remove all accumulated material between the hours of 6 A.M. and 8 A.M. in summer, and between 7 A.M. and 9 A.M. in winter. The workmen employed during these early morning hours are engaged during the rest of the day in making supplementary sweepings, wherever needed, and in cleansing the gutters (repeated twice a day), in washing out the public urinals, in disinfecting and sprinkling the streets, and in cleansing the cells of the police stations, etc. This supplementary work should be completed by 4 P.M., but it is sometimes prolonged later in the day, principally in bad seasons, on account of the extra work required, such as the spreading of sand or gravel on steep and slippery streets, and the special sweepings in front of certain public buildings.

In parts of the town devoted to business, the sweeping operations may be advantageously conducted during the night, but in sections where the people reside, no work of this kind should be permitted during hours allotted to rest and sleep. The noise created by the operations is a sufficient reason for strictly prohibiting all such work. The early hours of the morning may be suitably selected for the performance of the work in the populous parts of the town. In other localities, such as the outskirts of the city, there can be no objection to sweeping operations being conducted during the entire day, the force and apparatus employed in the central parts of the town in the early morning being transferred to these sections during the remainder of the day.

Street-sweeping Machines.

To secure systematic, regular, and efficient work, the whole town should be divided into sections, and a given number of laborers, sweeping-machines, and carts for removing the products of sweeping, should be assigned to each section; the number required for doing the work properly within the given hours being easily and accurately determined after a little experience. The streets should be divided into routes, and a cart assigned to each route, so that the removal of the collected dirt of the entire town may take place within the prescribed hours. All these details can be arranged with the greatest precision, if the work is regularly prosecuted under intelligent supervision.

The employment of machinery for sweeping the streets is no longer a matter of experiment. The great value of these accessary appliances has been fully and satisfactorily demonstrated. No city can afford to dispense with their services. With their aid, the frequent cleansing of a large city is no longer considered impracticable. The two principal kinds of apparatus in use are the sweeping and loading machine, and the simple side-sweeper. The former sweeps the dirt into a box, or receptacle, connected with the apparatus, which, when full, can be emptied and replaced by the use of a simple contrivance, without the driver getting off the machine. The latter sweeps the dirt into a winrow, which at each subsequent passage of the machine is pushed further to one side, and is thus progressively swept to the gutter of the street, where it is made up into heaps to be carted away. In Paris the systems of M. Blot and M. Sohy are in use, both one-horse side-sweeping machines. They are simple in their construction and in their functions. They are composed of a framework upon two wheels drawn by a single horse, and having a seat for the driver. On the rear of the machine is found the sweeping apparatus, which is composed of an inclined roller armed with bristles of *piassava* set in a spiral form. The brush receives its rotary movement by a series of gears in communication with one of the wheels of the frame. By means of a system of levers the driver, from his seat, puts the sweeping-brush in operation, or stops it, at will.

The machines are employed in all kinds of weather, and as well upon ordinary stone pavements as upon the macadamized roads and asphalted areas. The cost of one of these mechanical sweepers is two hundred dollars. The annual cost of maintenance is about forty dollars, independent of the removal of the piassava brushes. A brush will do constant work for a period varying from 160 to 180 hours. Each renewal costs about fourteen dollars. The weight of either of these machines is about 1,650 pounds, which can be drawn by one horse with ease. At the speed of a horse's pace, a machine is capable of sweeping 5,500 square metres per hour, which corresponds to the work of ten ordinary laborers.[1]

A somewhat similar sweeper, patented by Mr. Edson, has been used in Boston and Philadelphia, with good results.

Smith's sweepers, both the sweeping and self-loading machine and the simple sweeping machine, have also been in use in the latter city. They are serviceable and efficient, and have proved satisfactory after a trial of several years. The two-horse "side-sweeper," represented by Fig. 87, is the most effective apparatus. It consists of a cylinder of brooms

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[1] Notice sur le nettoiement de la voie publique, Paris, 1876.

placed diagonally across and under the truck. Gearing connected with the driving-wheel gives motion to the broom-cylinder, so that the latter revolves as the truck advances, with greater or less rapidity, according to the speed of the horses. The oblique action of the broom throws the dirt to one side in the form of a winrow. When this machine is operated alone, the dirt thus collected in rows at the sides of the street or in the centre must be heaped up and thrown into carts by manual labor. It may be worked with great advantage in connection with the "sweeping and loading machine," represented at Fig. 88. The construction of this apparatus is very similar to that of the apparatus shown in Fig. 87, except that there is added a dirt-box, or receiver, into which the dirt is deposited as it is swept from the surface of the street.

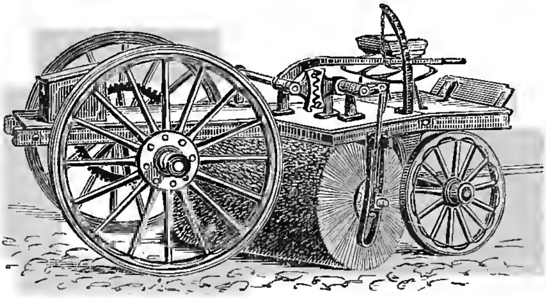

Fig. 87.—Smith's two-horse "side-sweeper."

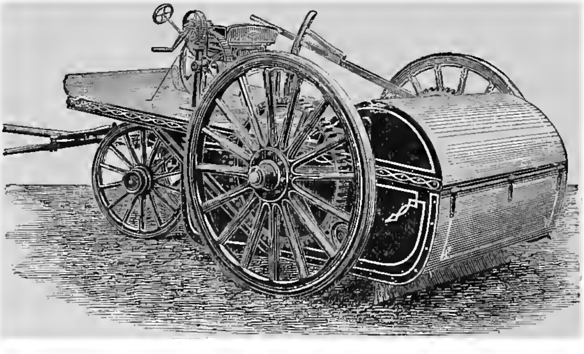

Fig. 88.—Smith's combined street-sweeping and loading machine.

By the use of this complete appliance, or rather combination of appliances, the dirt can be swept and collected from the street surface simultaneously, and by this means the objectionable small heaps are avoided. The receivers are emptied at convenient places, more or less distant, according to the amount of soil on the streets, and from these places of general deposit it is removed in ordinary carts. By avoiding the small heaps there is a saving of time and labor, and the result of the work is more complete and satisfactory.

There are single-horse machines of both descriptions, but those shown in Figs. 87 and 88 are decidedly the most efficient for ordinary stone pavements, especially the cobble-stone pavement. Split rattan or piassava are the materials of which the brooms are composed.

The sweeping in dry weather should be preceded by sprinkling of the surface of the streets with plain water, or with water impregnated with disinfectants, when required. This is done either by hand watering-pots, or by watering-carts provided with a distributing-pipe perforated with very small openings, from which fine jets of water are scattered in sufficient quantity to allay the dust. This act is immediately followed by the sweeping, and the dirt, when collected, should be immediately removed while in the moist state, to prevent it from being scattered by the wind or by passing vehicles. The carts in which the street dust is removed—if in the daytime—should be provided with tightly-fitting covers of wood or canvas. The thorough washing of the gutters every day, and the frequent cleaning out of the basins of the sewer-inlets, should be enjoined as an important part of the service of town-cleansing.

The removal of ice and snow, particularly the latter, is a difficult, laborious, and expensive, but very important, branch of the public service. In this country it is almost totally ignored, but in large European cities this work is considered necessary for the comfort and health of the citizens, and is accordingly required to be performed. Besides the interference with traffic, and the inconvenience and discomfort to pedestrians, there is the impediment offered to the regular cleaning of the streets. Hence, filth collects and becomes mixed with snow, and at every thaw the street surface is covered with filthy slush. At the final melting of the snow and ice in the spring, the mixed accumulations of weeks, perhaps of months, are exposed to view. It may be weeks before this offensive matter, already in a state of decomposition, is entirely removed and the streets are again restored to a condition of cleanliness. In the meantime the convenience, comfort, and even health of citizens have been seriously compromised.

The very busy streets require the removal of the snow as much to facilitate traffic and aid locomotion as for any other reason; but there are other localities which demand it on the ground of the preservation of the public health. In many of our northern cities there are small streets, densely populated, which serve as the channels of drainage for the houses located upon them. The liquid refuse discharged into the street-gutters is often a condensed form of sewage. After the opening of winter, a mass of snow and ice soon accumulates in these narrow passages, and its bulk is increased, from time to time, by the addition of rubbish and of snow from sidewalks and yards. A ridge, several feet high, is soon formed from curb to curb, rendering the street impassable to the ash- and garbage-carts, and hence the refuse of the houses is soon deposited upon the icy mass outside. The only passage for the house-water is along the sidewalks, over which it occasionally flows into the basements of the adjoining houses, and defiles the interior air. The cleansing of these streets is not effected until the mass of ice and snow has thawed, which is not until the spring has well advanced, and until after the perpetuation of a nuisance, rendered almost intolerable at each recurring thaw. These small streets, though obscurely located, are the very ones from which the snow and ice should be kept removed, on the score of public health. These instances show the importance of incorporating in the street-cleaning regulations, provisions for the removal of snow and ice, at least from some localities.

In Paris the snow is removed from the principal streets by the use of the wagons employed in the street-cleaning service, and, in addition, by the employment of the large two-horse wagons belonging to the omnibus companies, which are placed at the disposal of the city by special agreement. There are also other wagons employed, for which special contracts are made with the rubbish-carters at the beginning of each winter. The preparation for removal is made by the forces employed in the street-cleaning service, aided by the citizens, who are obliged to clean their sidewalks, to free the gutters from snow and ice, and to heap up the snow upon the street immediately in front of their respective premises for a short distance from the curb line.

When the snow commences to thaw, the process of melting is facilitated by turning on the public hydrants. The street-sweepers are then put in operation, and the slush is rapidly swept into the inlets, whence it passes into the sewers, the temperature of the sewage favoring the further transformation of the melting snow into water. Steam has been tried as an auxiliary; but it has proved to be impracticable, and, therefore, its use has been given up.

The annual cost of removing snow from the city of Paris is about $35,000, but in some years it is double this amount.

Street Sprinkling.

The sprinkling of the surface of the streets in the warm and dry season conduces both to comfort and to health. It has the effect of cooling the atmosphere, but its main advantage is recognized in settling the dust, and in preventing it from being wafted about by the action of the wind. It is rarely the case that this work is performed by the municipal authorities, though properly belonging to the public service. It is most commonly undertaken by private parties, under the sanction of the town administration, and the expense is defrayed by the occupants of premises specially benefited by the enterprise, by subscriptions at so much for the season. The use of the public hydrants is granted free of cost. Additional sprinkling is also done by individuals in front of their respective premises, by the use of hose and sprinklers; but this is very irregular and inconsiderable. The regular sprinkling is performed by means of large casks or wooden reservoirs mounted upon wheels, to which is attached a distributing-pipe—usually placed at the rear end of the apparatus—

perforated with small openings, from which the water is ejected to a considerable distance. The discharge of water is regulated by a lever under the control of the driver. The service of street-sprinkling should be regulated by strict municipal ordinance, in order to prevent abuses. One of these is the constant wetting of the flag-stone crossings; another and more serious one is the application of water in inordinate quantities, whereby the street-surface is made muddy, and is disfigured with puddles of dirty water, especially wherever the surface drainage is defective.

Attempts have been made to improve the method of sprinkling—so as to avoid as much as possible the inconvenience which the act frequently occasions—by the employment of *deliquescent salts.* These salts, applied directly or in solution, tend to keep the surface in a moist state, and therefore a less frequent sprinkling is required. Mr. Darcel, chief engineer of the city of Paris, first experimented with the refined chloride of calcium. Not being sufficiently soluble for use in the sprinkling-carts, it was applied by hand. The effect lasted for five or six days. This article being very expensive, the unrefined chloride of calcium, which contains some chloride of manganese and is only half as costly, was substituted in its place. It was applied in the same manner. Although double the quantity was used, the effect lasted only three days, and even then it was necessary that the air should be moist; on the failure of this condition of the atmosphere, a light sprinkling with plain water was necessary. Mr. Darcel therefore gave preference to the pure chloride, but he remarks that its use would be very expensive.

Mr. Hornberg, engineer-in-chief of the public streets of Paris, also made experiments with deliquescent salts. He employed the pure chloride of magnesium, which is very soluble in water. The salt was applied in the evening in the dry state or in solution. The result was very satisfactory during the first twenty-four hours; but on the second day, a light sprinkling was necessary; on the third day, two were required; and on the evening of the third day, a renewal of the chloride had to be made. The use of this material, even by the aid of the sprinkling-carts, was expensive; and the advantages of this and other similar salts have not been sufficiently prominent to justify their employment in the place of the ordinary sprinkling, which has the advantage of refreshing the air as well as of preventing dust. However, in dry seasons, when there is a scarcity of water, recourse may be had to these salts with profit.[1]

Disinfectants.

The use of disinfectants is sometimes required to prevent and counteract the offensive products of decomposition of organic matters upon the streets, in the gutters, catch-basins of sewer-inlets, urinals, etc. But in no case should these agents be used as a substitute for thorough cleanliness. The remark of Mr. Simon in regard to houses having offensive smells

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[1] Notice sur le nettoiement de la voie publique, Paris, 1876.

may also be applied to the public ways in a like condition, that artificial deodorizers will no more serve in the stead of cleanliness and ventilation than, in regard of persons, perfume can serve instead of soap and water.

The agents commonly used are the chloride of lime, sulphate of iron, sulphate of zinc, and carbolic acid.

Chloride of lime disengages chlorine-gas, which has the effect of decomposing sulphuretted hydrogen, sulphurous acid, hydrogen, the ammoniacal salts, and all the volatile products of organic decomposition. It may be employed wherever urine and fæcal matters are deposited, and for disinfecting foul gutters, inlets, and offensive holes in badly-paved streets, etc.

The sulphates of iron and zinc may be employed under the same conditions. They are non-volatile, and therefore do not destroy the offensive odors produced by decomposing organic matters; they will, however, prevent the formation of these offensive effluvia by their application to the substances from which the bad odors are given off. The sulphate of iron is a very cheap article, and is a very useful agent for disinfecting gutters and inlets. It has the disadvantage of producing a yellow stain upon objects with which it comes in contact. The sulphate of zinc is more energetic, but more costly; it disengages no odor, nor does it produce any stain. It is used in Paris in cleaning and washing out the market-houses and cellars, and spaces adjoining the market-houses.

Carbolic acid has been recommended, both for its antiseptic and disinfectant qualities. It cannot be called a deodorizer, in the sense that chlorine is; and it is hardly proper to depend upon it as an aërial disinfectant. But it does exert a powerful influence upon the processes of fermentation, which it arrests and prevents. As it destroys the low forms of animal and vegetable life, and restrains and prevents putrefactive changes, it is an especially valuable agent for disinfecting urinals, latrines, spaces in and about market-houses, gutters, public streets, etc. In summer time it may occasionally be applied to the streets and gutters liable to defilement, such as those in the poor quarters of the town, and around market-houses, slaughter-houses, and the like. It may be applied by sprinkling-carts, in the proportion of one part of the acid in 1,000 parts of water. For the other purposes indicated, it may be used in solution, in the proportion of one part of the acid to 20 parts of water, up to one part of the former to 100 parts of the latter, according to circumstances.

Many other agents are in use, a full description of which, together with their uses, will be found in the chapter on Disinfectants.

The Cleansing of Market-houses.

The cleansing of the market-halls, and the passage-ways and streets in their vicinity, is a very important part of the sanitary administration of a town, and should therefore receive the most minute care. The most rigid regulations, and constant surveillance to compel their enforcement, will be required to prevent the evil effects from the decomposition of vegetable and animal refuse matters accumulated during each day. A daily sweeping and washing of these places, and a daily and even more frequent removal of the refuse substances, will be required to preserve a perfect hygienic condition. The use of chlorinated or carbolated water may be resorted to with advantage in the summer season. The pavements of the market-halls and of the passages and neighboring streets should be made of non-absorbent material, such as asphalt, and they should be thoroughly drained.

The greatest care should be exercised in collecting and removing the refuse-matters. Galvanized iron receptacles will be very serviceable for this purpose, and those used for the collection of the animal matters, such as entrails of fish and poultry, should be hermetically sealed before being removed. Butcher's offal, and all other substances liable to rapid putrefactive changes, should be removed in the same careful manner. If carts are used they should be water-tight, and should be provided with tightly-fitting covers. The offensive practice of removing these substances in open carts, exposed to the full influence of the sun, should be strictly prohibited.

The Removal of Ashes and Dry Refuse.

The removal of ashes and dry refuse from houses is a part of the street-cleaning service. These materials, collected in proper receptacles, in the manner already indicated, should be placed upon the pavement at the moment of the passage of the ash-cart, and at no other time, lest they interfere with locomotion or be overturned into the street, and thus create a nuisance. They are immediately emptied into the ash-carts, and the receptacles are removed from off the public ways. The ash-carts should be large, well-constructed vehicles, provided with tightly-fitting wooden or canvas covers to prevent the scattering of the dust by the action of the wind or by the jolting over the stones. They should be required to be kept in a clean condition. The streets should be divided into routes, and the collections should take place at regular intervals, and as near as possible at the same hour on the days of collection. This will be a great convenience to housekeepers, and will prevent the setting out of the receptacles before the approach of the wagons. A daily removal of ashes and refuse may be required in some cases, in others a bi-weekly or even weekly removal will suffice. This must be determined by local circumstances. However, the more frequent, as a general rule, the better. When the refuse-matters are very offensive, it will be necessary to have the carts cleansed and disinfected before they are returned to the public streets. Suitable depots should be provided at convenient distances from the town, where the refuse can be deposited and assorted preparatory to its utilization. The pernicious practice of shooting this material into sunken places and upon lots in the environs of the town should be strictly prohibited, since these "filled-in" places may become the sites of dwellings in the near future.

The Removal of Kitchen-garbage.

The removal of kitchen-garbage is also a branch of the street-cleaning service, and one which requires the minutest care in its organization and administration. This material should be taken away daily. There can be no deviation from this regulation in the summer season. The management of the garbage-vessel upon the premises has already been described. Drained of its liquid contents, it is delivered to the collector at the moment of his arrival, which is announced by the ringing of a bell. The receptacle, promptly returned, should be immediately cleansed before being used for fresh deposits.

The same regularity and systematic management are required in regard to the garbage-carts as has been shown to be necessary in the case of the ash-carts. They should be constructed in the best possible manner. They should be water-tight; and the interior should be coated with some impervious material, to prevent absorption of the liquids. Tightly-fitting covers should be provided, to prevent the escape of offensive odors or the spilling of any of the contents. It is of the greatest importance that these vehicles should be thoroughly washed out and disinfected, to prevent them from becoming offensive. Instead of the garbage-carts, air-tight receptacles, about the size of a barrel, may be used and transported upon a truck. Each receptacle is provided with a tightly-fitting cover, which is adjusted to a rubber gasket, and firmly fixed by means of clamps. Such receivers are now used for the removal of night-soil without offence. They are more easily handled and cleansed, and have a great advantage in the case of large establishments, such as hotels, restaurants, etc. The material need not be disturbed; the entire cask, when full, is sealed up, and removed to the truck, and an empty one left in its place. The material should be removed beyond the environs of the town, to be disposed of according to circumstances. It is often utilized by feeding it to swine, or by converting it into a compost.

The Defilement of Open Spaces in Towns.

The defilement of open spaces and vacant lots in towns and cities by refuse-matters, dead animals, stagnant water, house-slops, fæcal matter, etc., is of frequent occurrence. The refuse-matters from houses, trades, manufactories, the street-sweepings, garbage, and the like, are deposited upon these spaces in the environs of towns, for the want of other convenient places. The most stringent regulations and the most constant watching are required to prevent such nuisances from being perpetrated. It is generally the fault of the town authorities in not providing depositories for waste-matters, which must of necessity be carried out of the populous districts. In the warm weather these matters undergo decomposition, and pollute the surrounding atmosphere. The soil also is defiled by soakage, favored by the rainfall; and the well-water of the neighborhood is exposed to the risk of contamination. Rain-water collects in the depressions of the surface, and, polluted by oozings from the foul accumulations, it takes on a still more offensive character from exposure to the hot rays of the sun. Sickness in the neighborhood is often attributed to these conditions, and with reason.

But it is not only upon the outskirts of towns that these nuisances occur. The vacant lots in the more populated parts are also converted into depositories for all kinds of filth. At times, when unobserved, people deposit upon these open spaces ashes, garbage, slops, refuse of all kinds, and even fæcal matter. The effluvia from these places render impure the air of the neighborhood; and the drainage affects the soil under and about the adjoining houses.

To prevent these nuisances, there should be provided well-selected depositories for all refuse-matters of a putrescible nature; the inclosing of all open spaces within the populous parts should be required and enforced, so as to prevent access for improper uses; ordinances prohibiting, under penalty of a fine, the improper disposal of refuse should be made operative; and, most of all, a well-ordered and complete system for removal of all refuse-matters should be provided, so as to avoid the necessity of infractions of sanitary rules.

The *defilement of the surface* in towns and cities, *by urine and* even *fæcal matter*, is not an uncommon occurrence. Where proper conveniences are not at hand, alley-ways and by-places are frequently made use of by persons for the purpose of attending to the wants of nature. In parts of the town populated by the poorer classes, fæcal matter as well as urine finds its way into the small streets, courts, and alleys, generally on account of the shameful want of proper conveniences in the dwellings. To prevent these nuisances from being created, the municipality should require every house to be provided with suitable water-closets, and cause to be erected in proper places, public water-closets or privy conveniences and urinals. Accommodations of this kind are very rarely provided in this country, simply for the reason that there exists a strong popular disgust for anything that may partake of the nature of immodesty. Another objection sometimes urged against these places is that they are liable to become offensive public nuisances. Such may be the case where there is a want of proper care. Both of these objections may be easily overcome by properly locating the "conveniences," and so constructing them that, while they are easily accessible, they afford a screen from public view and privacy to those who enter them; and, further, by carrying out a thorough system of inspection and cleansing, so that these resorts shall never remain unserviceable or in a filthy condition.

These accommodations are requisite, not only as a means of promoting public cleanliness and decency, but also of contributing to public comfort and of preventing needless suffering, and even disease. They are especially required in much-frequented localities. They should be simple in their construction, well lighted, and well ventilated, and managed with the most scrupulous care, so as to maintain perfect cleanliness and freedom from all offensive odor. In northern towns it will be necessary, in the winter season, to cut off the supply of water. In its stead, fresh sawdust is sometimes used in the urinal-basins.

Surface Defilement in Small Towns and Villages.

In small towns and villages, the absence of underground drainage and the want of systematic disposal of refuse-matters frequently give rise to serious nuisances. The house-slops, which consist of kitchen-water, some urine, and of the foul washings of the premises, are often either thrown upon the surface, or allowed to flow into ditches or open channels upon the roadway, from which they soak into the ground, or are discharged into the nearest water-course. The house-refuse is often accumulated upon the premises, or is thrown into the public road. Excreta also frequently form a part of the contents of the ash-pit placed near the house. From all these sources, there is constant danger of pollution of air, ground, and water.

The chance of surface impurities getting into the water of wells (which are usually located close to the houses) is very great. This is more particularly the case when shallow wells are used. The soakage-water from the ground of a considerable area about the well will gravitate toward it, and, if the surrounding soil is constantly saturated with filth, the water itself will necessarily be very impure. It sometimes happens that filth accumulated upon the surface of the ground is washed directly into the well. The water-supply is sometimes taken from small streams polluted by soakings or by surface-washings. Underground water-cisterns, if not well cemented and protected by good coping-stones, may be as liable to contamination from surface-washings and soakage as ordinary wells.

Another source of surface-defilement in villages results from bad privy management. The fæcal matter is often deposited upon the natural surface of the ground or in a superficial hole, whence the fluid filth drains away into the soil, or overflows upon the surface. This manner of accumulating excremental matter, with its attendant effluvia and soakings, is very liable to give rise to a serious nuisance, by infecting the atmosphere and contaminating the water-supply.

In addition to these sanitary defects, so common in villages, there are others which arise from the keeping of animals in situations close to houses and the sources of the water-supply. Horse-stables, cattle-sheds, pig-pens, manure-heaps, are often badly managed and ill-cared for. Their location, contiguous to dwellings, is of itself a nuisance, but the offensive outflows upon the natural surface or soakage into the soil of liquid filth from neglected accumulations of refuse-matter, when in close proximity to human habitations, must of necessity prove injurious to health.

The public roads of villages are too often only common dirt-roads with open ditches at the sides to afford drainage. Refuse thrown upon the surface mixes with the dust or mud, and is left to decompose. Road-cleansing receives but little attention. The shallow ditches, which were properly intended to carry off the surface-water, are frequently resorted to for getting rid of house-slops, which are carried over the surface to the ditches, or are conveyed into them by badly-laid and open-jointed drains. The outlet to such of the contents of the road-ditches as does not soak into the ground, is either into some small neighboring stream, or into field-ditches near the village. It is needless to speak of the consequences which must arise from this pernicious plan of drainage.

The problem of rural sanitation is, from the very nature of the case, difficult of solution. Villages spring up without regulation. At first, the houses are scattered, and surrounded by a wide space, and there is no difficulty in disposing of the liquid and solid refuse upon the premises. But in time, the houses become crowded together, and the spaces attached to them are then insufficient to properly dispose of the refuse matters produced upon the premises. The evils arising from the improper disposal of waste matters gradually become more and more apparent, until at last, by some unusual occurrence, most likely an outbreak of epidemic disease, they attract public notice.

It is then a matter of the greatest difficulty to remedy the errors of the past. The location is often such as should never have been selected. The houses are often ill arranged, destitute of proper conveniences, and many of them unsuited for dwellings. The sanitary defects which have been described, exist in all their forms. There may be a total absence of public drainage and of public scavenging, the accumulations of refuse being stored upon the separate premises, or removed according to the option of the individual householder.

The first thing to be done in the direction of improvement will be the organization of a sanitary board, which should be clothed with ample powers, and it may be necessary to apply to the legislature for acts by which the errors of the past may be in a measure corrected. As a rule, the improvements to old buildings will necessarily be limited, but all new buildings will be subject to sanitary provisions. Public improvements, such as sewers, water-supply, refuse-removal, road-macadamizing, ought to be introduced; but here the question of expense is generally the obstacle in the way of progress and sanitary reform. The limited number of houses in villages in comparison with the expense of these public works, makes the cost, per head, far greater than in towns, and, as the taxes are considered already sufficiently onerous, there is little disposition on the part of the people to increase their burdens, even though with the prospects of adding to their comforts and improving their health. Hence the reason for the slow progress of sanitary improvements in villages, even in those of considerable size, and in small towns.

In most villages, except those of very considerable size, or where the garden space is very limited, a system of public scavenging will hardly be deemed necessary, the facilities for disposing of refuse matters upon the premises generally being ample. Rubbish and garbage can be gotten rid of by fire, or, if not utilized upon the premises, can be disposed of without difficulty to collectors from the neighboring country. Excreta collected by the dry method may be disposed of in the gardens by digging it into soil, whenever the space is sufficient for this purpose; otherwise, arrangement may be made with some neighbor or some farmer, which will be satisfactory. So long as no nuisance is created by individual management of house-refuse, or by individual privy management, a public system need not be organized.

If the village be a large one, consorted action on the part of the inhabitants will be required in providing a system of scavenging. The dry earth may be procured and distributed, and the excreta mixed with the earth, removed at frequent intervals, either by contract or otherwise. The simple pail system, or the Goux system, may be adopted with advantage, provided the removal takes place at very frequent intervals. The expense of organizing a system will generally not be great, since, in an agricultural district, the manure will have considerable value.

In most villages the kind of closet-accommodation usually adopted is objectionable. It may be a simple wooden structure erected over a hole dug in the ground to receive the excrement, or a cesspit bricked up at the sides to prevent the falling in of the earth. Both of these contrivances are very offensive, particularly in the summer season. Sometimes a privy-vault is built close to the house, and a closet is constructed over it, so as to communicate with the interior of the dwelling. In some houses of the best class, water-closets are made use of, but too often the plan is seriously defective. The soil-pipe enters a privy-well adjoining the house, which is usually dug sufficiently deep to tap a porous stratum of the soil, with the object of securing an outlet for the fluid portions of the filth. The soil-pipe is usually not ventilated, and no adequate provision is made to prevent the entrance into the house of gases generated in the covered privy-vault. All these varieties of privy-accommodation, it will be perceived, are structurally defective. They permit of outflow upon the surface or of soakage into the surrounding soil, and are thus a source of offense and danger to health. The remedy for these defects should be radical. There is no better way of correcting the existing evils than by the adoption of some form of dry conservancy. Where water-closets are in use, which is rarely the case, it will be necessary to remove the cesspool as far away from the house and water-well as possible, and also to take the precaution to make it absolutely tight, so that no part of its contents can, under any circumstances, filter away into the soil. Other precautions, already suggested, should be carried out.

The use of the flush-tank for collecting the house-water and disposing of it through permeable drains carried just beneath the surface and within reach of the roots of plants, or, in other words, subsoil irrigation, may be turned to advantage in disposing of the waste from water-closets. This waste should enter the drain some distance beyond the flush-tank, so that whatever deposit may be left, will be swept away by the scouring action of the water discharged periodically from the tank. This means of the disposal of sewage, in the few cases of water-closet accommodation met with in villages, will answer the purpose very well. A proper garden space, located some distance from the house and the source of water-supply, will be required, and care will have to be taken that the main drain which conducts the sewage to the soil to be irrigated, is of proper material and well constructed.

In almost all villages the slop-water is disposed of by a system of surface-drainage, which often gives rise to a serious nuisance. The plan of subsoil irrigation, just alluded to, has been recommended, by Mr. Moule, Colonel Waring, and others, as the best solution of the difficulty. Its practical application has recently been tested in the village of Lennox, Mass., "where a flush-tank, having a capacity of five hundred cubic feet, periodically delivers its contents through a system of about ten thousand feet of two-inch tile lying twelve inches below the surface, and which has an uncemented joint at every foot of its length." According to Colonel Waring, under whose advice and supervision the work has been carried out, the results have been entirely satisfactory. This general plan of disposal of village slops may be substituted for the ordinary sewerage-system, with the advantage of creating no nuisance at the outfall. The liquid refuse engendered on separate premises may be dealt with after this same manner, whenever there is ample garden space at hand.

Various other plans have been suggested for the disposal of slop-water. One of these is that devised by Dr. Bond, which consists in the use of a precipitating tub and filter for clarifying the liquid refuse before allowing it to flow off upon the surface of the ground or into the open gutter. Dumb wells are sometimes used; but they are not to be recommended as a safe means of disposal of the slop-water of villages. For a few cottages this plan will be satisfactory, provided the well be located far away from all sources of water-supply. To carry it out successfully the soil should be of a porous nature, so as to permit the slop-water to gradually soak into its pores. A full exposition of the subject of disposal of the slop-water of villages will be found in a brochure recently published by Dr. Fox, to which reference may be made.[1]

The roadways of villages should be macadamized, or made of coarse gravel, so as to furnish a good surface for traffic, and afford free drainage. The gutters should be constructed with particular care, since a large amount of slop-water will be discharged into them. A very good form of gutter is made of stone laid upon concrete. It has the advantages of being easily cleaned and of preventing soakage. Superficial drains, made of terra-cotta pipe, and provided, at intervals, with catch-pits, are very satisfactory. They keep the surface dry, prevent accumulations of slop-water in the gutters, with the attendant effluvia and soakings. If the roadbed is kept in good order, and the surface is cleaned at frequent intervals, and the deposits in the catch-pits are regularly cleaned out, there will be but little danger of obstructions forming in the pipes. Should such occur, the expense of removing them will be inconsiderable, as the

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[1] The Disposal of the Slop-water of Villages, London, 1877.

pipes are placed near to the surface of the ground. Means of flushing and of ventilation should be provided. If there is any likelihood of a nuisance being created at the outfall of the drains, the sewage may be purified by irrigation, sub-irrigation, or intermittent downward filtration.

Nuisances in connection with the keeping of animals are very common in villages and small towns. The pig-pen is a usual accompaniment of the village lot. Too frequently it is situated close to the dwelling-house, or sufficiently near to cause an offence. The removal of the pens to the most distant part of the lot, attention to cleanliness, and the provision of receptacles for the waste—which may be used as a manure—will remove the cause of complaint. In thickly populated villages, where the garden-lots are very limited in size, pig-pens should be abolished altogether.

The yards adjoining stables or barns, where the manure is stored for many months in the year, and into which the drainage of the buildings passes, are frequently offensive nuisances. There is usually no means of collecting the drainage from the accumulated manure, or of diverting the rain-water from the buildings away from the yard. The want of paving is another reason why these places and their approaches are generally in a filthy condition. If the barnyard is situated near the roadway, the outflow may pass into the road-gutters, and thus cause a public nuisance. To overcome these defects, it will be necessary to pave the barnyard and its approaches and, in a special manner, that portion of the yard set apart for the deposit of the manure; to provide a tank or receptacle for the liquid manure, with pump attached; and to carry off the rain-water from the buildings and surface in appropriate channels.

These nuisances are always offensive, and they may be dangerous to health. Says Dr. Wilson: "Under any circumstances, the proximity of the well to a pig-sty, pig-wash tank, or an undrained farm-yard, should be viewed with suspicion, even though the water be found to be good at the date of examination. A well so situated is almost certain to become polluted to a dangerous extent some time or another; but it is seldom that the warning is attended to until sore-throat, diphtheria, dirt-fever, or diarrhœa breaks out in the family; and then, if the premises in question happen to have a dairy attached to them, there is no saying how far disease which has thus been engendered may spread. Indeed, there is no class of premises in rural districts whose sanitary condition should be more carefully looked after than dairy-farms; and such fatal outbreaks as those of Islington, Annerly, Mosely, Marylebone, and the recent outbreak at Eagley—all of them traceable to polluted milk—afford the strongest possible argument that every dairy where milk is sold should be licensed, and that no license should be granted unless the sanitary condition of the premises is in every respect satisfactory."[1]

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[1] Sanitary Work in Villages and Country Districts, London, 1876, p. 38.

Surface Defilement by Fæcal Matters.

The accumulations of fæcal matters in courts, alleys, and confined places, are said to have the same injurious effects as sewer-air. The effluvia from such accumulations are less hurtful in proportion to the amount of atmospheric dilution.

The use of fæcal matters for manure is not generally considered to be injurious to health. When turned under the surface, these matters soon lose their offensiveness, on account of the absorbing and deodorizing powers of the earth. As has already been seen, the evidence against the influence of sewage-farms in the production of disease is very strong. Some few instances have been recorded in which the spreading of excreta upon the ground for agricultural purposes has been followed by sickness attributable to fæcal emanations;[1] but these cases are not sufficiently numerous to warrant a general conclusion. In China, where all fæcal matters are carefully stored and applied to the soil, there is no evidence that evil effects have been produced by the practice. In the villages, the air is often redolent with fæcal odors; yet no disease likely to arise from such effluvia, such as typhoid fever or dysentery, has been traced to this cause.[2]

However strong may be the evidence against the deleterious effects of applying human excrement to the ground, common prudence requires that the practice should be limited strictly to rural districts. The application of decomposing excreta to the surface is an exceedingly offensive operation, and, unless the material is speedily mixed with the earth, it will cause a further annoyance, and possibly be damaging to the health of the people living in the neighborhood. The practice of using fæcal matters as a manure for truck patches in the environs of towns, which are more or less populated, and where the water-supply is derived from wells, is known to be an offensive nuisance, and it may be dangerous to health. Here the conditions are altogether different from those existing in the country. The manure is lavishly spread upon the ground, and it is frequently the case that it is applied in a liquid form to growing vegetables without digging it into the soil. The odors from such farms may be only offensive, but the surface-washings, if they enter the wells depended on for the water-supply, will produce the same effects as would result from contamination by leaking cesspools. Shallow wells may become polluted by soakage-water, though, unless the fæcal matter is applied in too large quantities and too frequently, the oxidizing powers of the soil may be sufficient to counteract any injurious effects from filtration. This manner of using human excrement in the immediate suburbs of towns, which are partly built upon, and where the water-supply is taken from wells, is a nuisance, and possibly injurious to health, and should, therefore, be forbidden.

"*Made ground.*"—In towns, more or less of the ground used as sites

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The Sewage Question, p. 189.

[2] Customs Gazette of China for 1871.

for buildings is artificial—that is, made by filling up inequalities in the surface with all kinds of refuse, such as ashes, street dirt, house and trade refuse which is composed of a very considerable amount of animal and vegetable substances. The organic matters undergo decomposition, and in course of time the soil becomes purified by oxidation and by the mechanical action of rain. The time required for the disappearance of the impurities is variable. It depends mainly upon the amount of decaying matters, the free access of air, and the free motion of water in the soil. In the artificial soil of Liverpool, made largely of ashes and not very impure, Drs. Parkes and Sanderson found that it took about three years for the animal and vegetable matters to disappear: textile fabrics were destroyed less rapidly; while wood, straw, and similar substances were only partially decayed in three years. When the amount of impurities is excessive, a much longer time will be required. The process of purification is greatly impeded, in the absence of drainage, by the collection of stagnant water, which excludes the atmosphere. Under these conditions a soil may remain impure for an indefinite length of time, and it is uncertain when it would be safe to use it for building purposes.

New-made ground should never be used for building purposes, until at least three years after the final deposit of rubbish has been made upon it. From the very commencement it should be well drained, to facilitate the natural process of purification by the free passage of air and water through it. The foundations of buildings should be carried down to the natural soil, and the sewer-pipes should be securely supported upon boards laid upon piles, or upon piers of brick-work; otherwise, by the subsidence of the soil, the pipes will open at the sockets and defile the surrounding ground to a dangerous extent. In the report on the sanitary condition of Liverpool, by Drs. Parkes and Sanderson, the following rules are laid down:

"1. No excavation should be used for the reception of cinder-refuse unless it is efficiently drained. This appears to us to be of especial importance in relation to the filling up of brick-fields. It is well known that the whole of the surface of clay is never removed, and there is always sufficient to form an impermeable basin, in which, in the absence of drainage, water constantly collects. We hold it to be of the greatest importance, for the rapid decomposition of whatever offensive material may exist in the 'cinder,' that it should be able to become dry. The only way in which this can be promoted or secured is by efficient subsoil drainage.

"2. As the vegetable and animal matter contained in the cinder-refuse decays and disappears in about three years, and is virtually innocuous before that time, we recommend that places filled up with cinder-refuse shall not be built upon for at least two years from the date of last deposit."

The promiscuous filling up of inequalities of ground is certainly an evil, and should be prohibited. This manner of disposal of refuse should be restricted to the less objectionable materials, and the practice should be subject to strict supervision.

SECTION III.

DISEASES CONNECTED WITH CERTAIN CONDITIONS OF THE SOIL.

The conditions of the soil affecting health exert their influence mainly through the medium of the air we breathe and the water we drink. There is also to be noticed the influence of moisture of soil as an independent factor, which affects health through its relations to the temperature and moisture of the atmosphere.

The general subject may be considered under the following heads:

1. Diseases connected with emanations from the soil.
2. Diseases connected with water in the soil.
3. Diseases connected with pollution of the soil.
    - *a.* Diseases connected with pollution of the air.
    - *b.* Diseases connected with pollution of drinking-water.

1. DISEASES CONNECTED WITH EMANATIONS FROM THE SOIL.

The principal diseases which have been attributed to telluric effluvia are, as stated by Parkes, paroxysmal fevers, enteric (typhoid) fever, yellow fever, bilious remittent fever, cholera, and dysentery. What the nature of the peculiar, subtle poison is that has the power of producing certain morbid states of the system, has not been determined with respect to any of these diseases. Whether it consist of minute particles of decomposing organic matter, or of living germs, neither chemical analysis nor microscopical examination has been able to discover. It can hardly be a gas. All that we know of it is that the production of the morbific agent, whatever its nature, depends upon some kind of decomposition taking place in the soil, requiring, as essential conditions, the presence of organic matter, heat, moisture, and air, and that it is largely conveyed to the body through the medium of the atmosphere.

It is hardly necessary to state that the *paroxysmal fevers*, both intermittent and remittent, are produced by terrestrial emanations, commonly referred to under the term *malaria*. These diseases are usually associated with the effluvia from marshes and low-lying and badly-drained situations, but they also occur in districts far remote from marshes, and even on elevated regions. Marshy districts are, however, the principal haunts of these diseases in nearly all countries. Various other diseases have been ascribed to the air of marshes, such as dysentery, diarrhœa, and some other gastric disturbances. Bogs, though generally damp, do not produce periodical fevers, but they are said to cause malignant catarrhs. (Cameron.) The deleterious effects of the air of marshes (malaria) are also manifested by impaired nutrition, anæmia, dyspepsia, disorders of the spleen (enlarged spleen), and sometimes liver abscess. The inhabitants of malarious districts are often easily recognized by their sallow, enfeebled appearance, which is probably due to imperfect or defective assimilation.

Yellow fever was at one time believed to be of malarial origin, and there are some who still entertain the view that the two agencies which produce yellow fever and paroxysmal fevers are inseparably associated, and are referable to telluric emanations. Certain conditions of the soil undoubtedly favor the development of the active agent of the disease. Climatic conditions, especially temperature, also exert an important influence upon its propagation. But its causation is more particularly associated with the presence of putrefying fæcal and other waste organic matters, such as accumulate about human habitations. Yellow fever is especially a fever of towns and cities, and not of country districts. The accumulation of filth, defective drainage, and general inattention to cleanliness, seem to be recognized as being intimately connected with the localizing causes, and this disease, like cholera and typhoid fever, has not inaptly been called a *filth*-disease.

There is no proof whatever that *cholera* is produced by terrestrial exhalations of the nature of the miasmata which engender periodic fevers. On the contrary, the outbreaks of this disease in sandy deserts, upon ships at sea, and in the severe weather of winter, indicate that its cause differs entirely from malaria. Cholera sometimes prevails in marshy and malarious regions, not because the soils of such regions are *per se* capable of producing the morbific agent, but rather because they form a favorable breeding-place for the development of the cholera germs from material introduced from without. Intermittent fever and cholera bear no particular relation to each other, and their prevalence at the same time must be looked upon simply as a coincidence.

The hypothesis that *typhoid fever* may be caused by emanations from the earth, occurring in the late autumn, and after dry and hot summers, is supported by a considerable weight of evidence. Warm, damp weather in the autumnal months causes active decomposition of vegetable matters, which is supposed to be favorable to the development of the poison producing this disease. Epidemics of fever have been attributed to the turning up of the soil, and to clearing ground covered with decaying vegetable detritus. "The exposure of the bottom of ponds and reservoirs in the season of heat and the season of decay—thus charging the air with the products of the decomposition of leaves, wood, and all forms of vegetable life, mingled with whatever the soil may add to these products, or changed, as the soil alone seems to have power to change them—is, of all others, the most frequent single cause assigned for the production of epidemics of typhoid fever in Massachusetts."[1] Colonel Waring, in his prize essay on the causation of typhoid fever, accepts the theory of the dissemination of the disease by the fæcal discharges of the sick; but he also advocates a theory of the development of the disease due to "the exhala-

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[1] Dr. Derby: Causation of Typhoid Fever, Second Report Massachusetts Board of Health, p. 171.

tions of decomposing matters in dung-heaps, pig-sties, privy-vaults, cellars, cesspools, drains, and sewers; or it may be (according to Pettenkofer) to the development of the poison deep in the ground, and its escape, in an active condition, in ground-exhalations." And he is also of the opinion that exhalations from freshly-exposed mud, as after the emptying of mill-ponds, are capable of exciting this disease. From an examination of data collected in the States of Massachusetts and Rhode Island, he concludes that typhoid fever is "a disease of the country rather than of the town," at least so far as these two States are concerned.

"The analogy," says Dr. Derby, "between fevers generally known as miasmatic (intermittent and remittent) and the continued or typhoid fever of New England, pointed out by Dr. Jackson, becomes very significant when we look at the experience of practitioners all over the State (Massachusetts) with reference to the bottoms of ponds and reservoirs laid bare in the seasons of drought. These are the very places which would surely give rise to intermittents in our southern country. Here they give rise to fever without remissions—to typhoid."[1] The other modes of causation of typhoid fever will be noticed further on.

2. Diseases connected with Water in the Soil.

Water in the ground affects health by causing a cold soil, and a misty, chilly condition of the atmosphere, and a disposition in persons living on or near such a soil to rheumatism, heart disease, neuralgia, and catarrhal complaints. Moisture is also an essential element in the production of the injurious emanations which arise from the decomposition of organic matters in the soil. Heat and air are also required in the processes concerned in the evolution of organic emanations. These organic processes are influenced, to a great extent, by the condition of the ground-water, which is the principal source of moisture to the layers of the ground lying above it. The rise and fall of the ground-water cause changes in the dampness of the soil above it, which facilitate or retard the activity of animal and vegetable decomposition. The fluctuations in the level of the ground-water, as implying variations in the moisture of the soil, have therefore been considered by Pettenkofer and others to exert an important influence in the production of disease. A uniformly low water-level is usually regarded as healthy, and a persistently high ground-water as unhealthy. But the most dangerous condition of the subsoil-water is that in which its level is subject to frequent, sudden, and violent fluctuations.

Of late years, new interest has been imparted to the subject of soil-moisture by the investigations of Drs. Bowditch and Buchanan, upon the connection of the causation of *consumption* with dampness of soil. Both of these observers, by independent researches, have arrived at the conclusion, that exposure to soil-moisture is one of the most prominent causes of consumption. Dr. Bowditch published his views in an address de-

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[1] Loc. cit., p. 177.

livered before the Massachusetts Medical Society, in 1862, and he then laid down the following propositions as embodying the results of his inquiry:

"First.—A residence on or near a damp soil, whether that dampness be inherent in the soil itself, or caused by percolation from adjacent ponds, rivers, meadows, marshes, or springy soils, is one of the primal causes of consumption in Massachusetts, probably in New England, and possibly in other portions of the globe.

"Second.—Consumption can be checked in its career, and possibly—nay, probably—prevented, in some instances, by attention to this law."

Subsequently, Dr. Buchanan, without knowledge of the observations of Dr. Bowditch, proved the relation between dampness of soil and phthisis to be one of cause and effect. He has shown, that, in certain English towns in which drainage-works have been introduced, and in which the ground has been made much drier, the mortality from phthisis has greatly diminished; and, further, that the rate of diminution in the number of deaths from this disease has been proportional to the extent of the drying of the subsoil. In some of these towns the improvement in the death-rate was very remarkable. In Salisbury the death-rate from consumption fell 49 per cent.; in Ely, 47; in Rugby, 43; in Banbury, 41; in other towns the rate of diminution was not quite so marked.[1] On the other hand, in towns which had been sewered with impervious pipes, and in which the subsoil had not been drained, there was no reduction in the death-rate from phthisis.

A still more elaborate examination of the distribution of phthisis in relation to conditions of the soil was subsequently made by direction of the privy council, and of this examination Mr. Simon remarks, that "it confirms, without any possibility of question, the conclusion previously suggested, that dampness of soil is an important cause of phthisis to the population living upon the soil." During the years which have elapsed since these investigations were completed, the theory of soil-moisture, as a cause of consumption, has been strengthened by additional evidence from different parts of the world, and it may now be regarded as a well-established law.

Excess of moisture in the soil is a common cause of mists and fogs, which injure health by producing chill. This condition of the soil gives rise to and intensifies sudden vicissitudes in the temperature of the atmosphere, which are deleterious to health. A humid state of the atmosphere is also injurious as a medium of conveyance of the impurities evolved from the surface of the ground.

In a recent report of an investigation of the drainage of one hundred and twenty-eight towns in Massachusetts, Dr. Winsor remarks, in regard to the influence of a damp soil upon the health of persons living over it, that "the class of diseases most frequently noted in connection with such [damp] cellars is 'inflammatory diseases of the respiratory organs,' espe-

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[1] See table, p. 418.

cially bronchitis. Next in order of frequency comes rheumatism, more particularly of the sub-acute order. Phthisis, pneumonia, and wasting chronic perversions of digestion, are also found by many of our correspondents to be common over such cellars. Also a lessened power of resistance to all diseases when contracted. No observer can doubt that a large amount of preventable disease is caused by damp cellars."[1]

Moisture of soil is one of the main factors concerned in the development of malaria. In addition, there are required, heat, air, and the presence of organic matter, especially of vegetable origin. The occurrence of malarious diseases is especially common in marshy regions. But other situations, such as damp bottom-lands, the oozy shores of streams, regions exposed to periodical overflows, and soils composed of impervious substrata, such as clay, which present an obstacle to the passage of water, are also favorable to the development of the agent which causes *paroxysmal fevers.*

The activity of the miasm varies with the degree of humidity. If malarious lands be submerged, so that no part of the surface is exposed to the action of the solar rays, the remedy is often complete. And this plan has often been resorted to when drainage is impracticable or not advisable (as in the summer season), with the result of improving the salubrity of the locality. On the other hand, by the evaporation of water from malarious lands, and the consequent exposure of the soil to the direct action of the sun, the conditions are especially favorable to the evolution of miasmata. The mode of cultivation of the land, at one time adopted in some districts of France, by alternately forming it into ponds and tilling it, was productive of the most serious consequences. The land was submerged for a period of a year or more, and at the expiration of this time the water was diverted into an adjoining field, and the drained lands subjected to tillage for one or two years, and then the process of ponding was again repeated. According to Fodéré, the country was rendered almost uninhabitable by this practice, the mortality amounting to about one-half the laborers. So long as the water covered the surface, no injurious effects were experienced; but so soon as the surface became desiccated the place became unhealthy. The exposure of river-beds and the bottoms of ponds and surfaces over which water has collected for a considerable length of time, has been followed by the production or increase of paroxysmal fevers. "The most favorable conditions for the development of this poison [malaria] are offered by marshes that have dried up; while their injurious influence is materially diminished as soon as heavy rains once more submerge the previously parched surface of the ground."

The variations of the ground-water are intimately related to the causes of *paroxysmal fevers.* "The rise and fall of the ground-water," says Parkes, "by supplying the requisite degree of moisture, or, on the contrary, by making the soil too moist or too dry, evidently plays a large part in producing or controlling periodical outbreaks of paroxysmal fevers

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[1] **Seventh Annual Report of State Board of Health of Massachusetts, p. 227.**

in the so-called malarious countries. The development of malaria may be connected either with rise or with fall of the ground-water. An impeded outflow which raises the level of the ground-water has, in malarious soils, been productive of immense spread of paroxysmal fevers." The rise and fall of the ground-water, by alternately wetting and drying the superficial soil, furnish conditions favorable, under the influence of a hot sun, to the decomposition of impurities in the ground, which is in some way connected with the evolution of malaria. Marshy lands which lie upon a retentive structure, through which the surface-water cannot drain away, are subject to frequent and sudden fluctuations in the level of the ground-water in seasons of rainfall. The season of heat, rainfall, and decay usually corresponds with the period of marked prevalence of the fever.

In districts free from marshes, but where the subsoil is of an impervious nature, the fever sometimes appears after the season of heavy rains, on account of the raising of the soil-water from obstructed outflow. Some such explanation as this seems applicable to Pola, a district of Istria, where, according to Jilck, the epidemic prevalence of malarious diseases corrresponds with the wet season, and is in proportion to the amount of rainfall. The fertile districts about Rome, which, centuries ago, were made habitable by the introduction of subterranean drainage, relapsed into their former state of unhealthiness after the neglect and destruction of these works, following upon the Gothic invasion. The appearance of malaria between 1866 and 1868, on the island of Mauritius, which had previously been exempt from diseases of this origin, has been attributed, in part, to the heavy rains and inundations. The outbreak of malarial fever which occurred at Kurrachee, in Scinde, in 1869, is said to have been caused by an excessive rainfall. (Parkes.)

The permanent lowering of the ground-water in malarious districts has had the effect of greatly mitigating, if not of entirely eradicating, paroxysmal fevers. The fen-lands of Norfolk, Lincolnshire, and Cumberlandshire are conspicuous examples of the salutary effects of deep drainage. These places, which were formerly pestilential marshes, have been rendered comparatively salubrious by improved land-drainage. Waring states that the town of Batavia, New York, which became so malarious as to be almost threatened with depopulation, has been rendered practically free from malaria by the drainage of the saturated lands situated near the town. He also mentions the case of Shawnectown, in Illinois, as a practical illustration of the removal of malarious disease by the free drainage of the soil. The skilful drainage of a portion of the Maremma district, in Italy, a notoriously malarious territory, by increasing the outflow and lowering the ground-water, has had the effect of greatly improving the health of that region. Instances could be multiplied to show the beneficial effects of draining on malarious lands.

The study of the subject of ground-water and its influences on disease, is especially interesting since the promulgation of the views of Pettenkofer relative to the connection of the variations in the moisture of the soil with the prevalence of *typhoid fever* and *cholera.*

The observations of Pettenkofer and Buhl, made in Munich, and covering a long series of years, clearly establish, so far as that city is concerned, a fixed relation between epidemics of typhoid fever and certain changes in the soil—as yet unexplained—which are indicated by fluctuations in the level of the ground-water. It has been shown, that, during the years 1855–'72, the periods of the greatest mortality coincide with the years of the lowest level of the ground-water, and the periods of the least mortality with the highest water-level ; and that the variations between the highest and lowest mortality corresponded with variations in the moisture of the soil, as indicated by changes in the level of the ground-water. With the rise of the ground-water there is a steady decrease in the number of fatal cases of typhoid fever, and *vice versa.* Low ground-water, especially when the water has rapidly fallen after having risen to an unusual height, is the condition of the water-level most favorable to the prevalence of the disease. Prof. Seidel has made a mathematical calculation from data covering a period of eight years, which proves that the probability is 36,000 to 1 that there is a connection between variations of level of soil-water and the prevalence of the fever.

According to the theory of Pettenkofer, the poison to which *enteric fever* is due is a product of the soil, and not of the water of the soil; the latter simply indicating, by its rise and fall, variations in the moisture of the ground. "The importance of these variations in moisture consists in their facilitating or retarding certain organic processes in the soil, while the ground-water itself may be quite harmless and innocent in the matter."

The fever seeds, or germs, which result from these obscure changes in the soil, rise with the ground-air and are communicated to man through the medium of the atmosphere. Such is the "ground-water theory" of the development of the poison of typhoid, proposed by Pettenkofer and elaborated by Buhl and others.

While it must be admitted that the relationship between the frequency of typhoid fever and the level of the ground-water has been proved to exist in Munich, this fact has not been as clearly demonstrated with regard to other localities. It is true that Virchow has shown that in Berlin typhoid fever increases as the ground-water falls, and decreases as the water-level rises, but, as Liebermeister remarks, the influence of the season of the year upon which typhoid and water-level depend, must first be eliminated before concluding a connection between typhoid and water-level in Berlin. Both Giessler and Rath deny this particular influence of the variations in the water-level, and attribute the typhoid fever of Berlin to polluted drinking-water. Buxbaum has cited, as proof of the correctness of the ground-water theory, the recent outbreak of typhoid fever in the barracks at Neustift, which appears to show a direct connection between the prevalence of the disease and the fall of the subsoil-water; but, as Parkes remarks, the frequency and extent of the connection remain to be determined.

These views as to the origin of enteric fever are considered to be too exclusive, and have not been generally adopted. English observers almost universally reject them, since they fail to explain the frequent connection observed in England between imperfect drainage or contaminated drinking-water and enteric fever, quite independent of any variation in the ground-water. (Murchison.)

The explanation of the connection between the frequency of the fever and the water-level is explained in this manner: When the level of the water in wells is lowered, the amount of dissolved and suspended matters in the water is relatively increased; and, moreover, the area of drainage for each well is greatly enlarged by the subsidence of the ground-water; and the foul matters containing the germs of the disease, from whatever source derived, are drawn from a greater distance, and are therefore more abundant in the water, the lower the latter is. As a rule, the water of any spring is purer in proportion to the height of its surface. A considerable amount of the impurities upon the surface of the ground, which would drain into it at a low state of the subsoil-water, is washed away when the latter stands at a high level. Adopting this view of the causation of the disease through the medium of drinking-water, it is evident, as Dr. Buchanan remarks, that the connection between the frequency of enteric fever and the height of the springs, would exist only in localities where the water-supply is drawn from wells. In support of this view, the fact has been pointed out, that in certain English towns, where the water-level has been permanently lowered by drainage operations, and pure drinking-water has been introduced from a distance, the mortality from typhoid fever, instead of increasing, as it should do, according to theory, has been reduced.

Pettenkofer and Buhl, while they admit the general importance of drawing the supply of drinking-water from a pure source, deny the agency of water in producing typhoid fever, especially so far as the case of Munich is concerned. Filth, they consider, will aggravate the disease; but it will not originate it. The true cause lies in the soil, the air of which acts as the vehicle of communication. The conditions which they hold to be essential to the development of the poison are rapid sinking of the ground-water after an unusual rise, air, heat of soil, the presence of animal matters, and the entrance of a specific germ. (Parkes.) Dr. Buchanan, and the English observers generally, admit the connection between the prevalence of typhoid fever and the falling of the ground-water; but hold that this is not of essential importance, the true cause of the disease being referable to pollution of drinking-water.

Neither of these theories appears to be opposed to the view, that the disease is due to the decomposition of filth accumulated in the soil by soakage from privy-vaults, cesspools, drains, etc., from which it finds its way into wells and contaminates the drinking-water, under circumstances especially favorable in dry weather, when the area of drainage is extended, and when the relative proportion of impurities in the water is increased; or, when it is exposed in the soil, especially after the subsidence of the ground-water, to the influences of heat, air, and moisture, which are favorable to the decomposition of organized substances and to the development of the poison, which is communicated to the atmosphere through the medium of the ground-air.[1]

A very similar theory has been advanced by Pettenkofer with regard to the causation of *cholera*. He holds that a fixed relation exists between the variations in the mortality from epidemics of cholera and the ground-water; that the poison is elaborated in the soil, and not in the water of the soil. The only influence which drinking-water can have on the spread of the disease is by occasionally acting as a means of conveyance of the germs engendered elsewhere; and, moreover, that the conditions of the soil most favorable for the genesis of the poison are porosity, pollution by animal matter, heat, and dampness, especially following a rapid subsidence of soil-water after an unusual rise, or, in other words, that a situation in a soil impregnated with organic matter, in which the specific germ of cholera is exposed to the action of heat, moisture, and air, is an indispensable condition of the prevalence of a widespread epidemic of the disease. A porous, filth-impregnated soil is certainly a dangerous one; but such a condition is not believed to be indispensably necessary for the development of cholera. The exclusiveness of the theory is what is objectionable. Well-authenticated instances of epidemic outbreaks of cholera have been reported in Germany, India, and elsewhere, in which the direct connection between variations in soil-water and the disease have not been observed. The observations made of the cholera epidemics in Zürich, in 1855 and 1867, especially in the latter year, show the disease to be unconnected with any variations in the subsoil-water.[2] In Berlin, and in Leipsic and Dresden, in 1866, the observations appeared to agree with the theory. In the former place the well-waters were found to be highly polluted.

The weight of evidence in India is opposed to Pettenkofer's views,[3] though there are instances which seem to establish their correctness, so far at least as the places are concerned where the observations have been made.

The investigations recently made by Lewis and Cunningham, at Calcutta, show that the prevalence of cholera in that city is closely connected with the state of the water-level. In their report, published in 1878, they remark, that "the period of maximum prevalence coincides with part of the period of maximum depression of the water-level, and one of the months of minimum prevalence with the month of minimum depression. Whilst the prevalence of cholera in Calcutta is associated with a low level

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[1] See on this subject articles by Pettenkofer, Buhl, Seidel, Buxbaum, etc., in Zeitschrift für Biologie, 1865–'70; Buchanan: Med. Times and Gazette, March 12, 1870; Pettenkofer: ibid., June 11, 1870; Virchow: Reinigung u. Entwässerung Berlins, 1873, p. 63; Archiv für klin. Med., 1873, p 237; Parkes: op. c., p. 333; Murchison: Cont. Fevers, p. 450; Ziemssen: Cyclopædia of Practice of Med., Vol. I., pp. 68–72.

[2] Lebert: Die Cholera in der Schweiz, Frankf., 1856; also Zehnder: Bericht über die Cholera-Epidemie d. J. 1867 im Kanton Zürich, Zürich, 1871.

[3] Townsend: Reports on Cholera in Central India.

of the soil-water, the data very clearly show that the absolute water-level in itself is of no importance." Investigations are still being carried on, the results of which will doubtless furnish data of value in determining this phase of the subject of the etiology of cholera.

Epidemic dysentery and *bilious remittent* fever have been classed among the diseases supposed to be influenced by variations in the level of the soil-water; but the evidence upon this point is as yet meagre and inconclusive. A soil contaminated with organic matter in a state of decomposition under the influence of heat and moisture, is frequently noticed in connection with outbreaks of these diseases. The propagation of epidemic dysentery is largely connected with local causes. Moisture of the soil is held to be favorable to its development. In the tropics the period of its prevalence is one in which, from rain or overflow, the soil is in a very moist state. It sometimes exists under conditions similar to those which are connected with the production of malarial fevers, a moist soil, and even a swampy condition of the ground, seemingly being an important factor in the development of the cause of the disease. At present it is impossible to give a decided opinion with regard to the influence of ground-water upon the propagation of these diseases.

3. DISEASES CONNECTED WITH POLLUTION OF THE SOIL AS A SOURCE OF—

a. Pollution of the air.
b. Pollution of drinking-water.

a. *Diseases connected with Pollution of the Air.*[1]

Emanations from the polluted soil of thickly crowded grave-yards, especially in densely populated localities, exert an injurious influence upon health. If not actually productive of any specific disease, they aggravate sickness and increase the rate of mortality. Vicq d'Azyr attributed an epidemic which occurred in Auvergne to the removal of bodies from an old cemetery. The neighborhood of the old cemetery of the Innocents in Paris became so sickly as to necessitate the removal of the remains. The air of the locality was highly impure. Candles were quickly extinguished in the cellars of houses near by. After the disinterment of the bodies the neighborhood ceased to be unhealthy. *Cholera* was very fatal in 1849 in the houses adjoining the old cemeteries of London. *Typhus* and other fevers were not uncommon near these old city grave-yards. *Diarrhœa* and *dysentery* are said to be caused by putrid emanations from cemeteries. *Malignant fevers*, *asphyxia*, and *suffocating catarrhs* result from exposure to the concentrated effluvia from putrifying bodies. (Rammazzini.)

On the other hand, well-regulated cemeteries, located on proper soil and in rural districts, exert no injurious effects upon the public health.[2] (See Interments, p. 538.)

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[1] See chapter on The Atmosphere: its Impurities, etc.

[2] See chapters on The Atmosphere and Public Nuisances.

The pollution of the air from fæcal matter thrown upon the ground has already been alluded to. Instances are on record in which *typhoid fever* has resulted from the manuring of the land; but they are not as frequent as they should be, if the effluvia produced by the application of excreta to the land were a common cause of this disease. In Chinese villages, which are surrounded with fæcal matter used in this manner, and where the air is contaminated with the offensive effluvia, typhoid fever does not exist, at least to any noticeable extent. The weight of evidence is against the influence of sewage-farms in the production of enteric fever. Dr. Clouston has recorded an outbreak of *dysentery* in the Cumberland and Westmoreland Asylum, which he traced to emanations from sewage spread over the land about 300 yards from the asylum. During the discontinuance of the practice for two years, there was an absence of this disease. But when the sewage was again applied to the land, dysentery again appeared. There was no possibility of the action of other causes, such as impure water, bad food, etc. The application of sewage to land may become dangerous to health by poisoning adjacent wells.

Accumulations of fæcal matter upon the surface of the ground in confined places near to dwellings, such as close courts, alleys, back-yards, etc., will produce the same effects as air from sewers and cesspools. Many instances of this kind are recorded in the English "Health of Towns Reports."

The effects upon health of emanations from the soil polluted by excreta—the cause of its most frequent contamination—and impurities from sewers and drains, and by all kinds of filth, are similar to those produced by the effluvia from sewers, drains, and cesspools, and will therefore be considered under this latter head. The diseases which have been attributed to these effluvia are enteric fever, diarrhœa, cholera, dysentery, diphtheria, pneumonia, and ophthalmia. There is some evidence that scarlet fever may be communicated in this way. Other effects from these effluvia have been observed, such as languor, loss of appetite, feverishness, headache, dyspepsia, anæmia, etc., etc. Sewage-emanations are known to aggravate the severity of all the exanthemata—erysipelas, hospital gangrene, and puerperal fever (Rigby); and it would seem that all diseases are more or less affected by these effluvia. (Parkes.)

Instances are recorded of poisoning by breathing the gases generated in sewers and cesspools, in some of which the consequences have been fatal, probably on account of inhaling a large quantity of ammonium sulphide, or of some other poisonous or fetid gas. In a case occurring at Clapham, in August, 1829, twenty out of twenty-two boys at the same school were seized, within three hours, with fever, vomiting, purging, and great prostration. One other boy had been seized the day before, and died in twenty-three hours; another boy died after twenty-five hours' sickness; all the rest got well. The cause of the disease was found to be due to the opening of a long-blocked drain at the back of the house. The contents had been spread upon a garden near the play-ground two days before the first illness occurred. The effluvium from the drain was very offensive; and the boys had watched the workmen while cleaning it out.[1] (Murchison.) A similar case came under Dr. Murchison's own observation, in June, 1861. A girl, nine years of age, was taken sick with febrile symptoms—vomiting, purging, and headache—followed by active delirium, and died in forty-seven hours after the beginning of the attack. It was found that the disease was caused by offensive effluvia which issued from the grating over a choked-up cesspool, close to which the child had been playing. Dr. Parkes states that he has known decided febrile attacks lasting several days, and accompanied with great headache and loss of appetite, to have resulted from exposure to the gases and effluvia from sewers. The outbreak of typhoid fever at Fort Lascaris, at Malta, caused by the opening of a drain, was associated with the prevalence of diarrhœa, dysentery, trifling pyrexial disorders, and diseases of "the primary assimilative organs." (Marston.)

The fetid gases of sewers, when breathed in a much diluted state in close atmospheres, give rise to headache, malaise, and general discomfort in delicate, sensitive persons only temporarily exposed to their influence; and they also appear to exert a depressing effect upon the general health, often manifested by derangement of the digestive system, in persons who habitually breathe such effluvia. (Simon.)

The effect of sewer-air upon men employed at work in sewers which are not obstructed or temporarily impure has been the subject of much discussion, and opposite views are held by reliable authorities. The statement that workers in sewers and nightmen are exempt from fever is, for the most part, founded on the observations of Parent du Chatelet and Dr. Guy; but, as Dr. Murchison remarks, "on close examination, they scarcely justify the inference drawn from them." The number of men examined by Parent du Chatelet was very small, and the majority of them had been employed in the sewers only for a short time. It is also to be observed, that a considerable proportion of the workmen were actually in hospital for two or three weeks with a "fièvre bilieuse," or a "fièvre bilieuse et cérébrale," which Murchison regards as examples of enteric fever.

Dr. Guy's observations were made before the different continued fevers were recognized as distinct diseases. The comparison was made between 101 brickmakers' laborers and 96 nightmen, scavengers, and dustmen; and it was found that the cases of fever among the former were greatly in excess. It has been supposed that the fever among the brickmakers' laborers was typhus, as it was attributed to overcrowding. Dr. Guy remarks that some of the cases of fever were produced by emanations from sewers and cesspools. (Murchison.)

It is stated by Parent du Chatelet, that the air of sewers cannot be endured by some men; but those who can work in them suffer from only trifling complaints, such as ophthalmia and lumbago. With these exceptions, the work is considered by the laborers themselves as not interfering with their health. On the other hand, both Murchison and Peacock

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[1] Continued Fevers, 1873, p. 472.

state, from their own observations, that enteric fever is not uncommon among workers in sewers.

Recent investigations upon the health of the sewer-men of London seem to indicate that it is not affected by their occupation; but the sewers of London and of Paris are, as a rule, well constructed and well ventilated, and in many of them the air is really not very impure. Letheby subjected the air of the sewers of London to chemical examination, and found that it differed but little from the external air. The sewers in this country are of a very different character; they are badly constructed, hardly ventilated at all, and carelessly managed. It is not at all improbable, that, if inquiry were made into the condition of the health of men habitually engaged at work in these sewers, the results would show an excess of disease among such laborers. And while it does appear from the few records at hand, that workmen connected with well-ventilated sewers do not, as a general thing, suffer any serious inconvenience, the statement that sewer-men do not suffer in health, as a result of their employment, cannot be accepted as a general conclusion; more evidence is required upon this point, for as yet the statistics are very imperfect.

Much interest attaches to the subject of the development of *typhoid fever* from the air of sewers and fæcal emanations. That this disease depends, to a great extent, upon the polluted air of sewers, cesspools, and of the soil, is proved by very strong evidence. The morbific agent, conveyed through the medium of the air, finds its way into houses from cesspools improperly located, or from drain-pipes imperfectly-ventilated or badly trapped, or from impure soil beneath and surrounding the dwellings. In some cases the disease has been confined to a particular part of the house, especially exposed to the effluvia from badly trapped drains; and, as the water-supply was apparently unexceptionable, there could be no doubt as to the source of the infection. It has been assigned as a reason why people of the better classes in towns suffer more from enteric fever, that their dwellings are, as a rule, more generally connected with sewers.

Houses located in the upper part of a town sometimes suffer more than those at a lower elevation, and this difference arises from a feature connected with the sewers. It is known that the sewer-gases tend to force their way toward the more elevated parts of the sewers, and if the drains of houses connected with them are not very efficiently trapped, the entrance of sewer-air is easily effected.

Offensiveness is not a necessary concomitant of infectious sewer-air. An instance is mentioned in Parkes' Hygiene of an outbreak of typhoid in a training-school, unmistakably traced to imperfection of traps, in which, on account of the smell of the effluvia being so very slight, it was not at first believed that the drains could be at fault. The outbreak of typhoid fever at Newbridge was caused by the entrance of sewer-air into the barracks during the temporary disuse of a ventilating shaft for the drains. All other possible causes were examined into and eliminated.[1] Riecke

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[1] Army Med. Reports, Vol. XV., p. 301.

gives a very unique and conclusive case of typhoid fever poisoning from fæcal emanations, in which two men who slept over a room where the evacuations of a typhoid fever patient were placed, were seized with the disease. It should be noted that there was no proper ceiling to this room, and there was but slight obstruction to the passage of air to the sleeping-apartment above. It has already been seen that the opening of a drain has been followed by decided cases of typhoid fever. The leakage of cesspools into the soil under dwellings has also given rise to the same effects.

While typhoid fever has prevailed in consequence of exposure to the emanations from bad sewerage-arrangements, on the other hand a marked diminution of the disease has uniformly followed the introduction of an improved system of sewerage. In twenty-one English towns, in which proper drainage-works had been adopted, the mortality from typhoid fever diminished 45.4 per cent.

There can be no doubt that *diarrhœa* is sometimes caused by sewer-air and fæcal emanations. It stands in close relationship with imperfection in the removal of sewer-matters. As a rule, it is most prevalent in badly sewered localities, and least so in districts which are well drained. A high degree of temperature and deficient rainfall appear to be the conditions most favorable to the evolution of fæcal effluvia connected with the spread of this disease. Children are the subjects most frequently attacked. *Dysentery* has also been traced to the same causes.

It is probable that *cholera* is occasionally spread by means of the air of sewers and cesspools; but there is very little evidence on this point. Parkes[1] gives a case (at Southampton) in which sewers were supposed to have played a part in the dissemination of cholera, and De Chaumont cites two cases which came under his own observation at Parkhurst, in 1854, the cause seeming to be due to the clearing out of an old latrine. According to Mr. Radcliffe, the outbreak of cholera in the City of London Workhouse, in July, 1866, was, in all probability, due to the sudden escape of sewer-air from a drain containing the evacuations of cholera patients.[2]

Polluted air from soils is another probable means of the introduction of the agent which produces cholera. According to Pettenkofer, the soil is the place in which the cholera poison is elaborated, and the "infecting matter is communicated through the medium of the ground-air." This observer admits that the disease is occasionally propagated by drinking-water; but it is in the soil, and not in water, that the cholera germ becomes developed and assumes its characteristic virulence.

The objection to this theory is that it is too exclusive. At the same time it must be affirmed, that, under certain circumstances, a polluted soil stands in a close relation to the prevalence of cholera, and that the connection between the effluvia from such a soil and cholera is occasionally a causal one. "The diffusion of cholera among us," says Dr. Simon, "de-

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[1] Sixth Report of the Med. Officer to the Privy Council, p. 251.

[2] Ninth Report of the Med. Officer to the Privy Council.

pends *entirely* upon the numerous filthy facilities which we let exist, and especially in our larger towns, for the fouling of earth, air, and water; and thus, secondarily, for the infection of man and whatever contagion may be obtained in the miscellaneous outflowings of the population."

The impure air from sewers and cesspools has been assigned as a means of propagating *diphtheria*, and instances are not wanting which seem to show that the poisonous decomposition of organic matter is in some way connected with the dissemination of this disease. Dr. de Chaumont says: "It would certainly seem as if the disease was capable of being generated by any sewage whatsoever, placed under particular circumstances," and he cites two cases in support of this opinion. One is that mentioned by Dr. Maclean, in which a number of children were struck down with diphtheria, supposed to have been caused by a leakage of sewage, which had been going on for months, in a part of the house immediately under the nurseries of the children. The heating-apparatus was placed near the point of leakage, and was thought to have intensified the evil by favoring the ascent of the poisonous effluvia. The other case was that noticed by Dr. Frank as having occurred at Cannes, in France, in which, by a defect in the sewer-ventilating pipe passing up close to the cupboard in a nursery, there was an escape of sewer-air into the room occupied by a number of children, with the effect of sickening the whole of them by diphtheria. Dr. Wilson remarks, that "in country districts isolated outbreaks of diphtheria, traceable to cesspool effluvia, are not at all uncommon. In these cases it is generally found that there is a water-closet in the house, which itself is badly ventilated, that the soil-pipe is never ventilated, and that the closet-drain discharges into a cesspool which is completely covered up, and only cleaned out at rare intervals. The consequence is that any gases generated in the cesspool have no outlet except through the water-closet and into the house, and hence result attacks of diphtheria, ulcerated sore-throat, and other badly defined ailments."[1]

From an inquiry instituted by the State Board of Health of Massachusetts, in 1875, respecting the predisposing causes of diphtheria, its prevalence, etc., it would appear that this disease has been most severe in the rural districts where there are no sewers, and where the drainage is generally very bad. The special connection between this disease and filth is not very clearly made out, although this condition is supposed to have the effect of aggravating the symptoms. The belief that the propagation of diphtheria is greatly influenced by contaminated air from sewers, privies, soils, etc., or, in other words, by filth-infection, seems to be gradually gaining ground; but at present the evidence is not sufficient to justify a decided opinion. The investigations which are now being carried on will doubtless, in a few years, settle this important question.

That *pneumonia* may be caused by sewer-emanations is shown by the remarkable case in the school at East Sheen. *Ophthalmia* is also pro-

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[1] Handbook of Hygiene, 1877, p. 71.

duced by the impure air arising from sewage-matters. According to Parent du Chatelet, the laborers in the sewers of Paris frequently suffered from slight ophthalmia, and de Chaumont mentions unequivocal cases of this affection originating from the foul air of a ditch into which sewage had been allowed to accumulate.

There is some evidence to show that *scarlet fever* is traceable to sewers, but it is inconclusive. *Venereal disorders* are greatly aggravated by sewer emanations. Parent du Chatelet is authority for the statement, that workers in sewers who persisted in the occupation when suffering from this disease inevitably perished. Two other disorders have been recently mentioned in English journals as being attributable to the effluvia of drains and sewers, namely, "*abscess of the cervical glands*, and a tendency on the part of *ulcerated surfaces* to become sluggish, and to yield to no ordinary management. Sometimes these ulcers take on a diphtheroid appearance."[1]

b. *Diseases connected with Pollution of Drinking-water.*[2]

The use of water defiled by impurities from the soil, whether from drains, cesspools, or other sources of decomposing organic matter, is a very frequent mode of origin of some diseases. Water contaminated by fæcal matters is perhaps the most noxious in its effects. And this is more especially the case when such matters are composed in part of the evacuations of persons sick of some one of the specific diseases, such as cholera or typhoid fever. The effects of the use of impure water may be very gradual, and may be manifested by general impairment of the health, without giving rise to any well-defined disorder. The principal diseases which have been attributed to this cause are diarrhœa, dysentery, cholera, typhoid fever, etc.

Diarrhœa is a very common effect of the use of impure drinking-water. Both animal and vegetable substances, especially the former, contained in water under certain conditions are capable of producing this disease. Sewage is a frequent source of contamination, and its effects are somewhat peculiar when the degree of impurity is very considerable. Parkes, Gibb, Oldekop, and others have noticed in such cases that the symptoms partake of the nature of cholera, vomiting, purging, colic, and even loss of heat, being not uncommon characteristics of the affection. Surface impurities washed into shallow wells by heavy rains have caused an outbreak of diarrhœa. An instance of this kind occurred in Prague in 1860. The water from grave-yards, which contains animal organic matter, is known to have given rise to attacks of diarrhœa.

Outbreaks of *dysentery* have been traced to polluted drinking-water, especially such as contains animal impurities. Water contaminated by sewage-matters from leaky cesspools and drain-pipes, by filth penetrating the soil about dwellings and gaining access to wells, by impurities washed

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[1] The Med. Record, 1878, p. 433.

[2] See chapter on Drinking-water.

into shallow wells by heavy rains, and by the drainage from cemeteries, has been demonstrated over and over again to be a means of disseminating this disease. The discharges of patients affected with dysentery are known to be infectious, and if admitted into drinking-water will, in all probability, have the effect of communicating the disease.

From the abundant evidence at hand, there can no longer be any doubt that water is a medium, if not the principal one, through which the poison of *cholera* is conveyed. Since Dr. Snow first announced his views, in 1849, respecting the propagation of cholera by polluted water-supply, founded on facts gathered at Horsleydown, Wandsworth, and other places, and subsequently confirmed by the evidence in the famous and conclusive Broad-street pump case, other and abundant evidence of the most unequivocal character has been collected, which goes to substantiate this opinion, and now many of the former opponents of the theory, among them Pettenkofer, admit that this mode of conveyance of cholera may occasionally happen. On the other hand, many competent observers, especially in Germany, have failed to throw the weight of their authority in favor of this view. The evidence in the cases of epidemic prevalence of this disease in Munich, in Saxony, in Baden, and in the small towns near Vienna, does not seem to be in favor of the spread by water. While this negative evidence should be allowed to have due weight, it should not be permitted to supplant the abundant and authentic positive evidence of the English observers. But Germany is not without instances, reported by very competent investigators, which go to show that outbreaks of cholera are traceable to pollution of drinking-water by sewage.

The evidence from India is, in the main, confirmatory of the same view. Drs. Macnamara, Townsend, and Cleghorn have all given some strong proofs of the fact, that dissemination of the disease is largely dependent on water-fouling.

Striking instances of cholera-propagation by the aid of polluted well-water have been furnished by other countries. Dr. Ballot's report on the spread of cholera in Holland shows, that, in all those towns in which rain-water alone was drunk, there were either no cases of cholera, or very few single cases, and these were supposed to have been imported ; while, on the other hand, where the water-supply was derived from the canals and wells, both highly polluted with sewage, the disease prevailed. "When places affected by the cholera were supplied with pure water, instead of the vitiated water, the disease disappeared." During the epidemic which prevailed extensively throughout that country, the city of Amsterdam, which is supplied with rain-water carefully collected and distributed, had only 4 deaths per 1,000, while in other cities and towns supplied with the water from the polders, or from the canals, the rate of mortality was from 16.8 to 17.7 per 1,000.[1] This country has contributed cases in support of the influence of foul water in spreading cholera. Dr. Chandler mentions cases connected with the epidemic of 1866. The prevalence of the dis-

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[1] The Med. Times and Gazette, May, 1869.

ease in a village near the Central Park, New York, was traced to the polluted water of the village-well. So also in the case of the Van Brunt-street pump, Brooklyn, which supplied over fifty families, among which the disease spread until the further use of the water was prevented.[1]

The fact that the mortality-rate from cholera in districts supplied with impure water has been very considerable, while in other districts, situated in the same locality, and placed under similar conditions, except that the water-supply was from a source less liable to contamination, it has been very slight—is evidence in favor of this mode of spreading the disease.

Dr. Simon has shown, that, in London, the houses supplied with water drawn from the river, after it had been polluted by a large quantity of sewage, furnished a death-rate from cholera equal to 13 per 1,000; while in other houses, situated under quite similar circumstances, except that they were supplied with a pure water, the rate was only 3.7 per 1,000. Frankland furnishes a number of illustrations of this very point.[2] Similar evidence has been presented by Schiefferdecker in connection with the great epidemics of cholera which have visited Königsberg from 1831 to 1866, in which, out of 5,543 persons attacked, 2,671 persons died. It was found that the inhabitants of those districts of the city which were supplied with impure drinking-water from the river Pregel and from wells were those chiefly attacked, while those supplied with pure water from a separate system scarcely suffered at all. (Lebert.) This same fact was attested by the experience in Berlin, in 1866, the year of the great epidemic of cholera. The disease occurred in 36.6 per cent. of the houses supplied with good water, while in the houses with bad water the proportion amounted to 52.3 per cent. (Parkes.)

The freedom of towns from cholera during its general prevalence, when such towns are provided with a water-supply free from ordinary sources of contamination; and the fact that places which were ravaged in former visitations of the disease have escaped at its subsequent returns, after the introduction of good drinking-water; and also the fact of the abatement of outbreaks following the use of pure water—are all arguments favorable to the theory that drinking-water is a potent element in the dissemination of cholera. The death-rate from cholera has greatly diminished in Calcutta since a better supply of potable water has been secured for that city. Pettenkofer states that entire towns in Germany, which suffered severely in former epidemics, have entirely escaped the disease during the late visitations; and he attributes the result to thorough and efficient drainage and purification of the water-supply.[3] Exeter, Hull, Newcastle-on-Tyne, Glasgow, and Moscow are similar instances, which have been mentioned by Dr. Parkes. Strong evidence of a similar character has been brought forward by Dr. Förster. He shows that in five towns in Silesia in which the water-supply is brought from a distance,

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[1] Public Health Reports, Vol. I., p. 541.

[2] The Water-supply of London and the Cholera: The Quart. Journ. of Science, 1867.

[3] Transactions Internat. Med. Congress, Philadelphia, 1876, p. 1063.

and is protected from contamination, there is an absence of this disease, and that, when imported, it never spreads in these localities.[1]

There is no proof that cholera may be produced by water uncontaminated with cholera evacuations, though it is probable that the use of water containing organic impurities, by causing a constant tendency to diarrhœa and by lowering vitality, predisposes to this disease.

In *typhoid fever*, as in dysentery and cholera, fæcal evacuations form the chief medium of communicating the disease. The poison developed during putrefaction of the alvine dejections is propagated by means of water as well as air. Says Sir W. Jenner, in speaking of infection from drinking-water: "The spread of typhoid fever is, if possible, less disputable than the spread of cholera by the same means. Solitary cases, outbreaks confined to single houses, to small villages, and to parts of large towns—cases isolated, it seems, from all sources of fallacy—and epidemics affecting the inhabitants of large though limited localities, have all united to support, by their testimony, the truth of the opinion that the admixture of a trace of fæcal matter, but especially the bowel excreta of typhoid fever, with the water supplied for drinking purposes, is the most efficient cause of the spread of the disease, and that the diffusion of the disease, in any given locality, is limited, or otherwise, and just in proportion as the dwellers of that locality derive their supply of drinking-water from polluted sources."

There are a great number of instances on record which tend to show the connection of typhoid fever with excremental pollution of drinking-water. The soakage from soils charged with sewage and excremental matters is a very common source of pollution of well-water. This is not surprising when we consider how little precaution is taken to prevent the filth from privies and drains and the defiled surface about houses from soaking into the surrounding soil, from which these foul matters find their way into the water of wells used for drinking purposes. Not only the water of wells, but that supplied to towns by aqueducts, has been the means of spreading the disease. In the latter case, as would be supposed, the extension of the disease has been more general.

Sudden outbreaks of typhoid fever have been caused by an irruption of sewage into wells from a break in a cesspool or drain, or from a soil in which the matter had gradually been accumulating. In this connection it is interesting to note that, when the poison is imbibed with water, the incubative period is usually short; and, as Dr. Budd remarks, this mode of infection is, in all probability, much more certain than when the poison is spread through the medium of the air. The outbreak of fever which occurred at Cowbridge, in Wales, in 1853, presented this fact: that, out of nearly one hundred persons who attended a ball at the town inn, more than one-third were shortly afterward attacked with the disease. There was good reason for supposing that the water used on that occasion was polluted, although a chemical examination had not been made.[2]

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[1] Die Verbreitung der Cholera durch die Brunnen, Breslau, 1873.

[2] Parkes' Practical Hygiene, 1878, note, p. 49.

The outbreak of typhoid fever at a convent in Munich, in 1860, was traced to the defilement of wells by sewage containing typhoid dejections. Thirty-one out of one-hundred and twenty of the inmates were affected with the fever, and four of them died. It is of interest to note that the disease disappeared after the water ceased to be used. Dr. Clifford Allbutt records a case which occurred at Ackworth, in 1870, where the water of a well, polluted with sewage, caused an outbreak of the disease soon after its special pollution by the discharges of a patient who had been brought home to the village while suffering from the fever.

Another instance, reported by the same observer, and quoted by Wilson, occurred at Bramham College, Yorkshire, in March, 1869: "It appears that two of the pupils were laid up with enteric fever in February, but circumstances showed that they must have contracted the disease before their arrival at Bramham. Towards the end of March, nineteen fresh cases occurred, and all of them about the same time. This sudden outbreak clearly pointed to some common cause which must have been in operation, and it was then discovered that the well used to supply drinking-water was contaminated by soakage from a soft-water tank, into which sewage-matter has passed from a broken water-closet pipe. The discharges of the first two patients had also passed into this tank, and had doubtless been the cause of the outbreak. Another important fact connected with this outbreak was the distribution of the disease amongst the pupils, it being confined to those who drank water, while those who drank beer escaped. As the same water was used for cooking purposes, it would thus appear that the poison must have been destroyed by boiling."

Dr. Wohlrab mentions a case, somewhat similar to one of those reported by Dr. Allbutt, in which an outbreak of the disease followed the defilement of drinking-water by the alvine dejections of a person who had contracted typhoid fever elsewhere. Parkes considers the case of the village of Nunney, recorded by Ballard, as furnishing very strong evidence in favor of the origin and propagation of the disease by a specific poison. The inhabitants of this village had been in the habit of using highly polluted water for years without causing the fever, when a person suffering from the fever came from a distant place, and the discharges from this person were washed into the stream from which the village drew its supply of drinking-water. The result was that "between June and October, 1872, no less than seventy-six cases occurred out of a population of 832 persons. All those attacked drank the stream-water habitually or occasionally. All who used filtered rain or well water escaped, except one family who used the water of a well only four or five yards from the brook." Dr. Parkes further remarks, that "the case seems quite clear—first, that the water caused the disease; and, secondly, that though polluted with excrement for years, no enteric fever appeared until an imported case introduced the virus. Positive evidence of this kind seems conclusive, and I think we may now safely believe that the presence of typhoid evacuations in the water is necessary. Common fæcal matter may produce diarrhœa, which may perhaps be febrile, but for the production of enteric fever the specific agent must be present."

It is very evident that water contaminated with sewage containing typhoid dejections will cause the disease; but, on the other hand, it is contended that the presence of the typhoid poison derived from the excreta of a person already suffering from the disease is not a necessary condition; that water polluted by sewage can disseminate the disease independently of typhoid excreta. Numerous cases have been reported from time to time, which seem to strongly support this view.

Again, there are those who hold the view, that enteric fever may be disseminated by drinking-water contaminated with other forms of decomposing organic substances besides fæcal matter. Such authorities as Murchison, Griesinger, Niemeyer, Liebermeister, Hudson, and Stewart support the view of the independent origin of enteric fever—that is, that this disease "may be generated independently of a previous case by fermentation of fæcal and perhaps other forms of organic matter." While, on the other hand, von Gietl, W. Budd, Parkes, and others believe that the presence, in the water, of the specific agent derived from the stools of an individual already suffering from enteric fever, is necessary for the production of the disease. Be this as it may, the conclusion is inevitable, and its relations to preventive medicine should not be undervalued, that water exposed to the danger of contamination by sewage or other forms of filth should be regarded with the gravest suspicion, as neither chemical analysis nor microscopic examination has been able to detect the subtle poison to which the fever is attributed. Water which is unobjectionable to the senses of sight, taste, and smell may, nevertheless, contain the morbific agents capable of propagating this and other forms of disease. It is therefore of the greatest importance to the health of a community that the strictest scrutiny should be exercised with respect to the supply of drinking-water. All possible sources of impurity should be promptly removed, and every effort made to secure an abundant and pure water; for it is clearly evident, that, to maintain the health of a community, one of the primary considerations is an abundant supply of water from which all possible dangers of contamination have been excluded.

In conclusion, it may be remarked that yellow fever, diphtheria, ulcerated sore-throat, erysipelas, and the "low fever" of country districts have all been attributed to impure water-supply; but there is not sufficient evidence at present to sustain this belief.

Disinfection of Excreta.[1]

Under ordinary circumstances, when healthy excreta are removed promptly and efficiently, disinfection is not required. But when these effete matters are retained about premises, and are accumulated in cesspools and privies, it is advisable to make use of chemicals to prevent decomposition and the evolution of offensive and hurtful effluvia. The

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[1] See chapter on Disinfectants.

alvine evacuations of persons suffering from infectious diseases should always be disinfected, no matter how complete may be the means for removing the excreta. The reason for this procedure is obvious when it is known that the fæcal dejections of the sick are the chief medium of propagating certain of these diseases from man to man. There is the very best reason for believing that, if this practice were always scrupulously observed, a vast amount of needless sickness and suffering would be prevented.

It has already been seen that the spread of cholera, enteric fever, dysentery, and some other diseases, is associated with circumstances of excremental filth. The contagium is known to exist in the discharges from the bowels, and, under favorable circumstances, may be the means of propagating the infection from the sick to the well.

"Choleraic discharges, if cast away without previous disinfection, impart their own infective quality to the excremental matters with which they mingle, in drains or cesspools, or wherever else they may flow or soak, and to the effluvia which those matters evolve; that if the cholera-contagium, by leakage or soakage from drains or cesspools, or otherwise, gets access, even in small quantity, to wells or other sources of drinking-water, it infects, in the most dangerous manner, very large volumes of the fluid; that in the above-described ways even a single patient with slight choleraic diarrhœa may exert a powerful infective influence on masses of population among whom perhaps his presence is unsuspected." In the same manner the evacuations in typhoid fever and perhaps other diseases are capable of communicating their own infective quality to any ordure with which they may come in contact, whether in drains, cesspools, or privy-wells.

Says Dr. Simon: "The argument which applies to the bowel-discharges of cholera and enteric fever, and which, in regard of them, rests on a very large quantity of detailed evidence, seems to extend by extremely strong analogy to every disease, whether nominally 'common' or 'specific,' in which the human intestinal canal is the seat of infected changes; chiefly perhaps to such diarrhœal and dysenteric infections as are exclusively or distinctively intestinal, but likewise, I apprehend, more or less, to every general infection (such, for instance, as scarlatina) in proportion as it inclusively infects the bowels; and it would thus seem probable that air and water, having in them the taint of human excrement, must often carry with them, whithersoever they pass, the seeds of current morbid infections."

Such being the case, it is important to guard against the danger of increasing the sources of communicating disease, by promptly and thoroughly disinfecting the intestinal discharges in all cases of disease in which there is the least suspicion of this mode of propagation; and such agents only should be employed as are capable of destroying not merely the specific contagia contained in the matters thus thrown off from the body, but also the material in the stools out of which the infectious particles may be evolved.

"It is requisite," says Dr. Carpenter, "to deal with the particles of contagion at their fountain-head; to act upon the nest-eggs freely as they come from the patient; to apply as much as one or two per cent. of the material used to the material to be acted upon, before it can find a new habitation, in which it may increase and multiply to an indefinite extent, if not so acted upon."

Insufficient disinfection is too frequently practised, the substances used often being comparatively inert, or, if effective, being used in too limited quantity. The object is to immediately neutralize the infectious matter, and to this end it is most important that the agents should be *well selected, freely used,* and *thoroughly incorporated* with the matters to be acted upon.

Various chemical substances have been used to accomplish this object. The most prominent among them are carbolic acid, chloride of zinc, sulphate of iron, cupralum, and chloride of iron.

The evacuations should be received at their very issue from the body in a vessel containing about half a pint of either of the following solutions:

A solution of four ounces of carbolic acid (Calvert's No. 4 or No. 5) in a gallon of (warm) water.

A solution of one quart of chloride of zinc (Burnett's fluid = 25 grains of the salt to every fluid drachm) in three quarts of water.

A solution of two pounds of sulphate of iron (green copperas) in a gallon of water. A solution of one quart of "strong solution of perchloride of iron" in a gallon of water.

In addition to the above chemical agents—which are the most reliable—other substances have been used, such as sulphate of zinc, sulphate of copper, chloride of aluminium, chloride of lime, permanganate of potassium, strong carbolic-acid powder, and terebene powders = feralum and cupralum, the latter consisting of sulphate of copper, alum, a little bichromate of potassium, and terebene.

To disinfect water-closets and sinks, use may be made of any of the above-mentioned solutions, of which a pint may be poured down the place two or three times a day. The constant disinfection of water-closets can be accomplished by the use of some one of the automatic disinfectors already described.

Privy-wells and cesspools may be disinfected by the use of large quantities of the metallic salts, preferably chloride of zinc and sulphate of iron. A solution of two pounds of the sulphate of iron in a gallon of water, or of one pint of Burnett's solution of the chloride of zinc in a gallon of water (to each of which two ounces of strong carbolic acid—Calvert's No. 5—may be added), are of the strength ordinarily used in disinfecting the contents of privies and cesspools. Unless freely used their power is wasted.

To accomplish a thorough disinfection, as much as one pint of any of these solutions must be used to each cubic foot of contents.

The disinfection of sewage has been discussed elsewhere.[1]

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[1] See section: The Disposal of Sewage.

THE ATMOSPHERE.

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THE ATMOSPHERE.

UNDER this title the air we breathe, and which forms the medium in which we live, will be considered in a variety of aspects.

For convenience, the following general order will be observed in treating the subject:

I. NORMAL COMPONENTS OF AIR—OXYGEN, NITROGEN, CARBONIC ACID. Water will be considered in a later section, under Meteorology.

II. IMPURITIES, ORGANIC and INORGANIC, with some special injuries due to them.

III. METEOROLOGY and CLIMATE.

IV. VENTILATION and HEATING.

COMPOSITION OF THE ATMOSPHERE.

There is no absolutely normal composition of the air we breathe; or, if there be, it is not at present known. It contains, however, in all cases, unless under purely artificial conditions, *two essential* elements, nearly (perhaps quite) invariable under normal circumstances, and *two accessory* elements, which vary extremely in amount, but are practically never absent. The first two are oxygen and nitrogen ; the other two, carbonic acid and water. Without either of the first two, air could not exist ; without the last two, air is scarcely found in nature. Their association, furthermore, forms not a chemical union, but a simple mechanical mixture.

Oxygen is the absolutely essential element for the support of animal life. Its functions in this respect will be described elsewhere. *Nitrogen* seems to act in the animal economy purely as a diluent or vehicle for the administration of oxygen.

Carbonic acid is far from such an indifferent agent; it is essential, but not to the animal kingdom, as far as known. To man it is simply a superfluous ingredient, harmless, when in moderate amounts ; to the vegetable world, on the contrary, it is a food which, together with water, often suffices to support the entire life of a plant. Hence, as related to life, in its broadest sense, the air may be said to be composed of nitrogen, oxygen, and carbonic acid; and this statement is, on some accounts, preferable to that which admits only oxygen and nitrogen.

Certain other substances, as ammonia, nitric acid, etc., are not valuable to man directly, and are by no means constantly present in air.

Water, in a gaseous form, is contained in the air, adding very little to its bulk. Speaking popularly, it is said to be held in solution by the air. Its value will be made the subject of future remark. Its great variations in amount, however, place it in a different relation from that held by nitrogen and oxygen, which, for the uses of man, constitute alone (or perhaps, we should say, with carbonic acid) atmospheric air in its strict meaning. Another point in which it holds a different relation is the fact that its amount is entirely independent of that of the other ingredients; it does not diminish when they increase, nor *vicè versa*, as is the case with the complementary gases, oxygen and carbonic acid. Nor is it a vehicle for oxygen; but a body of separate functions and laws, which will be spoken of in a special section.

The normal composition of air has been variously stated. Earlier observers have given figures slightly varying from those now accepted. A very pure air contains in 100 parts by measure:[1]

Nitrogen	78.98
Oxygen	20.99
Carbonic acid	0.03
	100.00

The mean of out-door air, as taken from various specimens, some very pure and some not so good, is given by Smith at:

Nitrogen	79.00
Oxygen	20.96
Carbonic acid	0.04
	100.00

Oxygen.

Roughly speaking, the air, if pure, should contain 20.99 per cent. of oxygen; an average air out of doors, 20.96; while Liebig and Graham assume 20.9 as a fair average for air. "Very bad" air begins at 20.6 (Smith).

Other observers have found varying results. Gay-Lussac and Humboldt, after many experiments, fixed on a mean of 21.00; De Saussure, 21.05; Berthollet, Davy, Thomas Thomson, Vogel, and Hermbstädt, from 21.00 to 21.59. Two observers, however, must be considered of leading authority, namely, Bunsen, who from 28 examinations of air at Heidelberg, ranging between 20.970 and 20.840, found a mean of 20.924; and Regnault, who from 100 observations at Paris gives the mean of 20.96.

It should be noted of the latter series that all his analyses give above

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[1] See R. Angus Smith on "Air and Rain," to which I am much indebted in this section.

20.9, except in unwholesome places with putrid waters. The following tables are given for further illustration.

ANALYSES BY REGNAULT.

100 specimens	in Paris	20.913—20.999
9 “	from Lyons and around	20.918—20.966
30 “	“ Berlin	20.908—20.998
10 “	“ Madrid	20.916—20.982
23 “	“ Geneva and Switzerland	20.909—20.993
15 “	“ Toulon and Mediterranean	20.912—20.982
5 “	“ Atlantic Ocean	20.918—20.965
1 “	“ Ecuador	20.960
2 “	“ Pichincha, higher than Mont Blanc	20.949—20.981
	Mean of all foregoing	20.949—20.988
	Mean of Paris specimens	20.96.

CLASSIFIED ANALYSES OF AIR FROM SCOTLAND, 1863-'65 (R. A. SMITH).

Sea-shore and heath	mean	20.999
Tops of hills	“	20.98
Bottoms of hills	“	20.94
All places not mountainous	“	20.978
Inferior parts of a town (in favorable, *i. e.*, windy, weather)	“	20.935
Lower marshy, etc., places	“	20.922
Forests	“	20.97
All together	“	20.959
Or	“	20.96

The following extracts, from a table by Smith, give certain points for comparing the numerical values with the sensible qualities of various sorts of air :

OXYGEN, PERCENTAGE IN VOLUME.

Scotland, N. E. seashore and open heath	20.999
Manchester, suburb, wet day	20.98
“ “ “	20.96
“ outer circle of city (not raining)	20.94
“ in city (fog and frost)	20.91
London, open parts, summer	20.95
Sitting-room feels close	20.89
Theatre, gallery, 10.30 P.M.	20.86
“ pit, 11.30 P.M.	20.74
Backs of houses and closets	20.70
Court of Queen's Bench (1866)	20.65
Mines, under shafts (aver. of many)	20.42
“ where candles go out	18.50
“ worst specimen yet examined	18.27
Very difficult to remain in for many minutes	17.20

ANALYSES FROM DWELLING-ROOMS (SMITH).

Before the door of a house in Manchester	20.96
In the sitting-room, not very close	20.89
In a very small room, with a petroleum-lamp burning, a good deal of draught	20.84
After six hours	20.83

It is a remarkable fact that the air at great elevations has often been observed to contain less oxygen than was found at lower levels. Dumas and Boussingault give the mean of nine observations, taken at Paris, as 20.864 per cent., while the mean of five, taken by them on the Faulhorn, was 20.774. Dr. William Allen Miller found air, procured from a balloon at the height of 18,000 feet, in August, 1852, to contain 20.88, while that taken from near the ground contained 20.92. Dr. Frankland found the air at the Grands Mulets containing 20.802 (with 0.111 per cent. of CO_2); at the summit of Mont Blanc, 20.963, with 0.061 of CO_2; at Chamounix, 20.894, with 0.063 of CO_2. Brunner made upon elevated places a series of observations giving from 20.750 to 20.867. These, and other similar observations, apparently confirmatory of one another in a general way, point to some cause, as yet unproved, for the diminution of oxygen in the upper regions of air.

De Saussure considered that the facts rather pointed to an increase of oxygen in the lower strata than to a diminution in the upper. This increase he ascribed to the action of vegetation, which is well known to consume carbonic acid and exhale oxygen.

Smith, however, proposes the converse hypothesis; he assumes that the organic substances floating in the air become consumed, oxidized, by the influence of ozone, producing as a result of their combustion carbonic acid.

Such increase of carbonic acid coincident with loss of oxygen appears in Frankland's analyses just quoted; and Messrs. H. and A. Schlagintweit found the carbonic acid to increase up to the height of 11,000 feet. "The diminution of the oxygen is probably a disadvantage—although to such a small extent is it so, that there is abundant compensation in the purification consequent on the removal of organic substances. We shall have, then, a distinct variety of air on mountains differing from that of the plains. In the one there would be more carbonic acid and less oxygen, with little or no organic matter—constituting mountain air; whilst the air of the plains would have more oxygen, less carbonic acid, and more organic matter."[1]

In the mountains of Scotland, however, air collected from the tops averaged 20.98 per cent., while that from the bottoms averaged 20.94;

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[1] A certain diminution in the proportion of oxygen at great heights above the earth is to be expected in accordance with Dalton's and Mariotti's laws. This view is sustained, upon theoretical grounds, by Hann, in the Zeitschrift der oesterreichischen Gesellschaft für Meteorologie, Bd. X., 1875, p. 25.

and a large number of observations from districts not mountainous or only partly so averaged 20.978. This seeming exception may be due (it is suggested) to the fact that the mountains of Scotland are not very high —the highest not attaining to 4,500 feet; and perhaps also to the close neighborhood of the sea, which would furnish by a direct transference over a few miles an air of nearly identical composition. The mountain regions which give low percentages of oxygen lie inland, where the air may be supposed to have taken up organic matter from the surrounding country.

The air of the German Ocean, as given by Lewy, contained from 20.423 to 21.010. These analyses were made by the aid of the balance; when, on the other hand, he tested by explosion by hydrogen, he obtained for the Atlantic Ocean (in mean of 33 analyses) a range from 20.96074 to 21.06099.

There is a good deal of evidence in favor of adopting the analysis for oxygen, instead of that for carbonic acid, as a test of purity. The test would be an absolute one if we could be sure of the uniformity of the proportion of oxygen in pure air. Taking this, as we probably may, for granted, we can say that the carbonic acid, in most cases, increases directly at the expense of the oxygen of the air, and that, therefore, a diminution of oxygen points logically to an increase of carbonic acid. There is this disadvantage in adopting the oxygen test, that it removes from view accidental impurities, such as the discharges from chimneys, which are certainly important.

Special illustration of the way in which oxygen diminishes under contaminating influences is furnished in the following tables of air from cities:

ANALYSES OF LONDON AIR (SMITH).

Middle of Hyde Park, average	21.005
Parks and open places, "	20.95
W. C. and W. (including some parks)	20.925
E. and E. C. " " "	20.86
S. and S. W. " " "	20.883
N. and N. E	20.857
Metropolitan Railway	20.70

MANCHESTER (SMITH), FROM THIRTY-TWO OBSERVATIONS MADE AT LABORATORY.

In very wet weather, in front of building	20.98
Average of all thirty-two	20.947
Behind building, in medium weather	20.936
In foggy frost, when the smoke of Manchester had little exit from the town	20.91
Over ash-pits	20.706

In the open parts of Glasgow the average was found to be 20.9293; in the closer parts 20.8890.

Further illustrations, under more specific conditions, are furnished by the analysis of the air from cow-houses and stables, in which six observations, made after the buildings had been opened in the morning, gave from 20.70 to 20.82. A long series of pairs of observations, taken simultaneously upon the air from the closet or midden behind the laboratory of R. A. Smith, and upon that in front of the laboratory, gives the average of 20.706 for the former, and 20.943 for the latter. To make the evidence more impressive, it may be stated thus: the average deviation from a standard of pure air (21.00) in the former case is 0.293; in the latter only 0.065, showing a deoxidation four and a half times as great in the midden as in the street.

Ozone, or Allotropic Oxygen.

This substance is obtained from oxygen by a variety of methods. It owes its importance to its intense activity, far more than to its amount, for the maximum quantity of ozone in the air never exceeds $\frac{1}{700000}$ of its bulk (Houzeau), and it is often entirely wanting. The first satisfactory account was given by Schönbein in 1840.

Ozone is simply oxygen which has assumed a new set of properties (allotropic state), in consequence of the action of electricity, or some other force; its elemental composition remaining the same. "It is now believed that it is an allotropic oxygen, in which three volumes are condensed into two, one of the volumes being in a different polar condition to the other two ($\overset{-}{O}\overset{+}{O}\overset{-}{O}$ = two volumes). Its molecular weight is 48, that of oxygen being 32; and its density is $1\frac{1}{2}$ times that of common oxygen. It decomposes slowly in the presence of moisture at 212° F., but decomposes instantly at a temperature of from 450° to 500° F., the ozone becoming ordinary oxygen. Ozone is only slightly soluble in water. At 32° F. 100 volumes of water dissolve $\frac{1}{2}$ volume of ozone (Carius). It is not soluble in solutions of acids or alkalies."[1] In its sensible properties, it is a colorless gas, having a peculiar odor of phosphorus, like that perceived during the passage of an electric spark.

Ozone may be obtained in various ways:

1. By electrical agency. The silent passage of electricity through damp oxygen is the method best adapted for its generation. The induction-spark may also be used. Its chief source in nature is atmospheric electricity. It may be generated by passing electricity through dry oxygen.

2. The oxygen set free at the positive pole of the battery in electrolysis of dilute sulphuric acid contains about $\frac{1}{250}$ of its bulk of ozone.

3. By slow combustion (eremacausis) of phosphorus in moist air, or in a mixture of moist hydrogen and oxygen; and by the slow combustion of ether and volatile oils (turpentine, etc.).

Ozone is also found in the oxygen produced by the action of light on growing plants (De Lucca); it is produced by aromatic plants and flowers

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[1] C. Meymott Tidy: Handbook of Chemistry.

(Mantegazza); it is also produced by contact with the juices of fungi (Schönbein, Phipson), and during all processes of fermentation, putrefaction, or decay (Phipson). It also originates during certain other processes of combustion and nascent action.

The following résumé of its laws of distribution is given by A. Meymott Tidy:

1. More ozone is present during the night than during the day, and most of all is found at daybreak.
2. More is found in winter than in summer, and least in autumn.
3. More is found at high than at low levels.
4. More is found on the sea-coast, and especially when the wind is blowing from the sea, than inland.
5. More is found in the country than in towns.
6. More is found after a thunder-storm than at any other time; least of all is found on damp, foggy days.
7. More is found with western than with eastern winds [*i.e.*, in England].
8. The maximum quantity of ozone in the air never exceeds $\frac{1}{700000}$ part its bulk (Houzeau). Its chief source is atmospheric electricity, and, as minor sources, the action of aromatic plants and flowers, etc.

Ozone is almost never found in the air of inhabited rooms.[1]

Ebermeyer[2] says that it is most abundant in the air of the open fields and in places of great atmospheric moisture. In the forests more is found in the upper strata of air, among the branches, than near the ground, owing, doubtless, to the absorption which occurs in the processes of decomposition. It is not found in large quantities over marshes and swamps during the season of active decomposition of vegetable matter,[3] though this is denied by Burdel.[4]

Ozone is an exceedingly powerful oxidizing agent. It corrodes cork, paper, animal membranes, caoutchouc, and other organic substances; its action on metals is very energetic. This property gives it great value as a disinfectant agent. It oxidizes with great rapidity the compounds of ammonia, phosphorus, and sulphur, which are so offensive in animal decomposition, instantly removing the odor. Its action on the lower forms of life is not sufficiently established; but it may probably be found to act as a germ-destroyer, as simple vegetable substances, such as mould, are completely destroyed when exposed to an atmosphere containing ozone (H. Carey Lea).

Ozone bleaches indigo, converting it into isatin. It is probable that the action of light and dew, by exposure to which cloth was formerly bleached, depends on the production either of ozonized air, or of nascent oxygen; and the same may be said of the modern process with chlorine.

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[1] Wolffhügel: "Ueber den sanitären Werth des atmosphärischen Ozons," Ztschr. f. Biologie, Bd. XI., pp. 419, 421, 440, 444.

[2] Physikalische Einwirkungen des Waldes, etc.

[3] Kedzie: Third Report Michigan Board of Health, 1875.

[4] Recherches sur les fièvres paludéennes, 1858.

The most popular, and the most sensitive, test for the presence of ozone depends upon this bleaching power (Schönbein). The test-paper is prepared by adding ten parts of best quality of starch to two hundred parts of pure water, heating this till the starch gelatinizes, and then dissolving in it one part (two parts, according to Tidy) of pure iodide of potassium. This paste is spread evenly with a brush on sheets of paper free from sizing, which are then rapidly dried by stove-heat, without exposure to sunlight, and then stored up in a covered jar, and kept from the sunlight till used. When exposed to air containing ozone, the salt is decomposed, changing the paper to blue. The depth of the blue tint produced on exposure is measured by comparison with a scale of colors, printed on a paper which is furnished for the purpose. In making the observations, strips of suitable length are cut, moistened, and hung up for a sufficient number of hours. Moffatt prefers dry paper.

In air containing no ozone, it is presumed that no discoloration takes place. This, however, is not absolutely correct; and hence a fallacy in the test. Chlorine, or the oxides of nitrogen, and some other agents, if present, produce a similar coloration. For this reason, ozonometry has not been so extensively and so satisfactorily pursued as the other branches of air analysis. Nevertheless, with all allowances made, the admitted powers of ozone render the subject one of great interest in its bearing upon climate and health.

Houzeau's ozonometer consists of neutral litmus-paper soaked in a dilute solution of potassic iodide, the potash set free by the ozone turning the paper blue. A piece of the litmus-paper without iodide is also exposed to the air at the same time; a comparison of the two papers indicating how far the action on the iodide paper may be due to ammonia in the air, and not to the action of ozone.

Ozone has a very irritating influence upon the respiratory mucous membranes; it is especially so to the eyes and nose, when breathed in any concentrated form. It may produce the symptoms of influenza, or cold in the head. In a very concentrated form it is irrespirable, and soon causes the death of any animal confined in it. These properties have suggested the causal relation between ozone and epidemics of influenza; a relation not established.

Oxygen containing $\frac{1}{240}$ of its volume of ozone is rapidly fatal to all animals, death occurring with intense congestion of the lungs, emphysema, and distention of the right side of the heart with blood (Redfern).

Air highly charged lessens the number of respirations and the strength of the cardiac pulse, and lowers the temperature from 5° to 8° F., the blood after death being found venous (Dewar and McKendrick).

Oxygen, on the other hand, is to so great an extent an indifferent gas that it can be breathed in very varying proportions without immediate toxic effects. In pure oxygen, at 75° F., a rabbit lives about three weeks, eating voraciously all the time, but nevertheless becoming thin. At 45° F. oxygen produces narcotism, and eventually death. When cooled by a freezing-mixture, it produces intense narcotism. When compressed under 3½ atmospheres, it produces violent convulsions, like those caused by strychnia, and ultimately death, when the arterial blood is found to contain about twice the normal amount of oxygen.

Nitrogen.

This gas is colorless, tasteless, odorless, and has less weight than atmospheric air. By the action of ozone, formed during thunder-storms, it may be converted into nitric acid; and the combination of the latter with organic impurities forms nitrate of ammonia, so often found in the rain of thunder-storms.

The gas-springs in the island at Paderborn contain 97 per cent. of nitrogen with 3 per cent. of carbonic acid; that at Lippspringe 83.25 per cent. nitrogen, 15.25 carbonic acid, 0.20 oxygen, and 1.30 atmospheric air.

The gas is, as above said, a vehicle for oxygen. It is incapable of sustaining life, and causes death by suffocation.

According to Küpper (quoted in Eulenberg), the "gemeinen bösen Wetter" and the "matten und stockenden Wetter" are chiefly composed of nitrogen, and are characterized in this case by specific lightness, and their inability to support combustion. The gas flows from clefts in rocks in many places, the exact seat of which is hard to find. When it forms 84 per cent. of the air, lamps go out; at 89 per cent. respiration ceases, and death, with convulsions, rapidly follows. These gases occur most frequently in long-disused shafts. In Düren seven men died within two and a half years of the effects of this gas. It is often found combined with carbonic acid and carburetted hydrogen; all three originate in coal and organic débris.

The poisonous effects of air impregnated with nitrogen are given as follows by Brockmann:—1st stage. Hunger for air, frequent deep breaths, oppression, and cold sweat. 2d. Mental oppression appears; but if the man escapes into pure air all the symptoms disappear. In a few cases there are secondary inflammatory symptoms referring to the brain and lungs. 3d. Stertor, icy coldness, loss of pulse, rigidity, loss of consciousness; the beats of the heart hardly perceptible, full, and very slow. After venesection the respiration becomes freer, and consciousness gradually returns. 4th. Death; the body icy cold and rigid.

Carbonic Acid.

This body sustains a peculiar relation to the atmosphere, being, on the one hand, always present as a normal constituent, and, on the other hand, owing its presence to the spoliation of another normal constituent, oxygen—*i. e.*, to combustion. And, owing to this fact of origin, and certain other facts, it occupies the place of an index of pollution when present beyond a given proportion. In this respect it has a very different rank from that of oxygen.

The balance between carbonic acid and oxygen in the atmosphere, continually disturbed in one direction by the animal kingdom, is constantly maintained by the vegetable. The former excretes carbonic acid, and consumes oxygen; the latter, for the most part, performs the opposite function. Fungi act like animals, in excreting carbonic acid.

An increase in the amount of carbonic acid ought in all ordinary cases to correspond with the diminution of the oxygen in the air. Lignin, mineral coal, peat, etc., derive the oxygen required for combustion from the air; so do the hydrocarbons; so does the animal system. Exception may be made for the combustion of special bodies, like nitre, chlorate of potassa, and gunpowder, containing large quantities of oxygen in their substance.

It appears that the rain also acts in diminishing the quantity of carbonic acid in the air. This it does by simple absorption; a power to dissolve carbonic acid being a well-known property of water. In addition, the rain, coming from high regions, is believed to bring with it (also in a state of solution) portions of atmosphere which contain more oxygen than that at lower levels (in cities), and to part with some of this oxygen at the same time that it takes up some of the carbonic acid; thus acting, in a double sense, as a purifier.

To the excretions of the lungs and skin, poured into the air of cities, must be added the product of fires and the decomposition of animal and vegetable refuse.

Immense amounts of carbonic acid are produced by burning fuel. It is estimated by Smith that 15,066 tons are daily poured into the air of Manchester from this source; in comparison with which the estimate of 330 tons for the product of respiration is a trifling amount. Nevertheless, by allowing duly for the space and height over which this is distributed, and the rate at which the wind blows (12 miles an hour), it appears that the percentages added together make the following table:

Carbonic acid from coals	.0091
Carbonic acid from expired air	.0002
Natural carbonic acid in air	.0300
	.0393

If this estimate be allowed, it shows that combustion and respiration, in a large city, are not sufficient, when taken together, to raise the *average* percentage above .04, or four parts in ten thousand, which is within the limits of what is stated by most observers to be a good average air.

Whence, then, comes the decided increase of CO_2 in the air of cities? It comes mainly from the confinement of the air in streets and alleys; and the lesson drawn from the preceding table should be, the importance of planning wide straight streets, and open spaces, and of avoiding closed squares of high buildings. The products of combustion and of putrefaction are very rapidly diffused, and the balance restored to nearly the normal point when fresh air in abundance is accessible. Sewer-gases discharged above the level of the housetops become nearly harmless. The air of parks in large cities is nearly equivalent to country air when analyzed; and a country air of fair purity is found up to the very limits of thickly-settled towns.

CARBONIC ACID IN TOWN AND COUNTRY COMPARED.

Places.		Percentages.
Scotland, purely rural and hilly districts,	Smith	.0336
Perth and outskirts, October,	"	.04136
Glasgow, opener parts, winter,	"	.0461
" closer parts, "	"	.0539
Manchester, minimum of suburbs,	"	.0291
" where fields begin,	"	.0369
" streets in usual weather,	"	.0403
" average of all town observations,	"	.0442
" during fogs,	"	.0679
" about middens,	"	.0774
London, open places, April,	"	.0301
" streets, "	"	.0341
" on the river, "	"	.0343
" average whole city, November,	"	.04394
" open parts,	"	.04115
Munich,	Pettenkofer	.05
"	Lange and Wolffhügel	.037
Madrid, outside walls, March,	De Luna	.045
" inside " April,	"	.052
Boston Public Garden (4 analyses), May,	Storer	.03006

The experiments of Théo. de Saussure, made with the greatest care in Switzerland during a period of several years, show a number of facts which appear to have the force of laws. Such are:

1. Analyses made at noon give uniformly a less percentage of carbonic acid than those made at 11 P.M.

2. Noon observations, 30 in number, give the mean amount for the three winter months as related to that for the three summer months, in the proportion of 77 : 100. The mean for January was .0423; for August, .0568. These results were not *uniformly* low, however, for winter, nor high for summer.

3. Eight observations, made at the middle of Lake Leman, at noon, and compared with those made on the bank, give a ratio of 98.5 : 100.

4. Twelve observations, made on mountain-tops, give in all but two cases a higher percentage of CO_2 than was found below or at the foot. It was further found that this percentage did not change by night, as was the case with observations on lower levels.

In stating the amount of carbonic acid present in air, the number of parts per ten thousand will usually be given. This is a convenient method, with the special advantage that it is easier to remember whole numbers (3, 4, 5) than decimals (.03, .04, etc.) Tables like the two preceding are converted by shifting the decimal two places to the right.

CARBONIC ACID IN AIR FROM CONFINED PLACES.

(Parts in 10,000.)

Place.	Time.	Observer.	Parts.
Tunnel in Metropolitan Railway, London, six observations	......	Smith.	14.52
Chancery Court, closed doors; 7 feet from ground	......	“	19.3
Chancery Court, closed doors; 3 feet from ground	.....	“	20.3
Strand Theatre, gallery	10 P.M.	“	10.1
Surrey Theatre, boxes	10.3 P.M.	“	11.1
Same, same evening	12 P.M.	“	21.8
Olympic Theatre	11.30 P.M.	“	8.17
Same	11.55 P.M.	“	10.14
Haymarket Theatre, dress circle	11.30 P.M.	“	7.57
Victoria Theatre, boxes	......	“	7.6
Effingham	10.30 P.M.	“	12.6
Pavilion	10.11 P.M.	“	15.2
City of London Theatre, pit	11.15 P.M.	“	25.2
Standard Theatre, pit	11 P.M.	“	32.0
Public schools of Philadelphia (average of 10 of various grades) in 1875	......	E. Thomson.[1]	13.15
Public schools of Boston (average of 25 primary and 15 grammar) in 1870	......	Storer and Pearson.[2]	14.5
Public schools of Michigan (average of 11 high and normal)	......	Kedzie.[3]	24.00
Annaberg, five schools	......	O. Krause.	39.9
School-room after two hours	......	Pettenkofer.	72.
A school, in March	......	Oertel.	56.7
Same, in July	......	“	41.
Wilhelm's gymnasium, in March	......	“	55.8
Same, in July	......	“	22.9
Celle, gymnasium, various rooms	......	Baring.	20.–50.
Celle, Volks-Schulen, most rooms	......	“	90.
Same, “ one room	......	“	120.
A Sunday-school, 80–100 children, before opening	......	W. R. Nichols.[4]	7.21
Same, an hour later	......	“	29.51
Same, half an hour later still	......	“	31.96
A Sunday-school, 350 persons	......	“	26.34
Same room, evening, 200 people and 10–12 burners	......	“	21.58
Berth-deck of the “Powhatan,” April, May, and June	11 P.M.	Th. J. Turner.[5]	11.8–19.6
“Swatara,” same period	......	“	15.03–26.62
“Ossipee,”	......	“	14.–18.
Highest amount found in an U. S. naval vessel	......	“	39.1

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[1] Report of the Committee appointed by the Board of Education to inquire into the Sanitary Condition of the Schools of the First School District of Pennsylvania, City of Philadelphia, 1875.

[2] Second Annual Report Massachusetts Board of Health, 1871.

[3] First Annual Report Michigan State Board of Health, 1873.

[4] Private communication.

[5] From records kept by medical officers of the ships.

Place.	Time.	Observer.	Parts.
Smoking-cars—15 analyses, ranging from 9.8 to 36.9—1874	......	W. R. Nichols.[1]	22.8
Same, other analyses	......	"	17.0
Passenger-cars (range from 15.9 to 36.7)	......	"	23.2
Sewer in Berkeley Street, Boston:			
90 analyses during pumping	......	"	8.5
25 " without "	......	"	10.4
Portsmouth Convict Prison: cells of 614 cubic feet, always occupied	......	Wilson.[2]	7.20
Same: cells of 210 cubic feet, occupied only at night	......	"	10.44
English mines, average of 339 examinations	......	Smith.	78.5

De Chaumont gives the following data from barracks, hospitals, and prisons. The figures are given in the original table as parts in 1,000; here pointed to give parts per 10,000. The observations of external air are instructive, as showing how wide may be the range of carbonic acid in air called "fresh." The fourth column of figures gives the difference between the carbonic acid found in the room and that in the outer air, a very important datum for determining the efficiency of ventilation.

	CO_2 in external air.	CO_2 in room.		Mean respiratory impurity.
		Largest amount found.	Mean amount.	
BARRACKS.				
Gosport New Barracks	4.30	18.46	6.45	2.15
Anglesey Barracks	3.93	19.71	14.04	10.11
Aldershot	4.40	14.08	9.76	5.36
Chelsea	4.70	11.75	7.18	2.48
Tower of London	4.20	17.31	13.38	8.98
Fort Elson (casemate)	4.25	18.74	12.09	7.84
Fort Brockhurst (casemate)	4.22	10.27	8.38	4.16
MILITARY AND CIVIL HOSPITALS.				
Portsmouth Garrison Hospital	3.06	20.57	9.76	6.70
Portsmouth Civil Infirmary	3.22	13.09	9.28	6.06
Herbert Hospital	4.24	7.30	4.72	0.48
Hilsea Hospital	4.05	7.41	5.78	1.73
St. Mary's, Paddington	5.63	15.34	8.47	2.87
MILITARY AND CIVIL PRISONS.				
Aldershot Military Prison—cells	4.09	34.84	16.51	12.42
Gosport Military Prison—cells	5.55	23.44	13.35	7.80
Chatham Convict Prison—cells	4.52	30.97	16.91	12.39
Pentonville Prison—cells, Jebb's system	....	19.26	9.89	....

As regards the amounts of oxygen and carbonic acid found in mines, the following illustrative data will be interesting:

R. A. Smith's analyses of 339 specimens from a large number of mines,

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[1] Second Report Massachusetts State Board of Health, 1871.

[2] Handbook of Hygiene.

almost all English, give a few instances of quite pure air—containing, *e. g.*, of oxygen and carbonic acid, respectively, 20.95 and .05;[1] 20.96 and .04; 20.96 and .06. These are few in number. The average of all his specimens gives oxygen 20.26, and carbonic acid, .785 per cent. (Compare standard of CO_2 in pure air, .03 and .04 per cent.) Of all the specimens, 10.67 per cent. were normal, or nearly so, in respect to CO_2; 24.69 per cent. were decidedly impure, and 64.63 per cent. were exceedingly bad.

Of the worst specimens, 99 contained less than 20 per cent. of oxygen; and of these, 13 contained less than 19 per cent. The worst were: 18.69, 18.67, 18.62, 18.52, and 18.27. And as regards the amount of carbonic acid, in the worst cases, it exceeded 1 per cent. (= 100 parts in 10,000, or twenty-five times the normal amount) in 98 cases, in 13 of which it rose above 2 per cent. (= 50 times normal amount); the worst containing 2.38, 2.40, 2.42, 2.51, and 2.73 respectively. The increase in carbonic acid was by no means exactly proportionate to the loss of oxygen.

Bodemann's eight analyses from the mines of the upper Harz[2] give an average of carbonic acid by volume = 1.1964 per cent.; of oxygen, 19.785 per cent. Smith, however, estimates the former at 1.396.

It is difficult to obtain accurate analyses of mine-gas. The "gemeine böse Wettern," analyzed by Hausmann,[3] gave in 100 parts, in two specimens:

	I.	II.
Nitrogen	81.4	86.52
Oxygen	13.75	12.12
Carbonic acid	4.83	1.36

The Cornish mines, as examined by P. Moyle,[4] in eighteen places, gave worse results. The average percentage of oxygen was found by him = 16.87; but Smith corrects the result by reference to the ascertained amount of carbonic acid, and gives, as the mean contents of oxygen, 17.55 per cent. The worst cases were those where 14.76 per cent. was reported (15.74, Smith), "four men at dead-end," where "lights burned with difficulty," and 14.51 per cent. (15.51, Smith), "forty-five minutes after firing."

Twelve ounces of gunpowder gave in burning 2.803 cubic feet of CO_2. This quantity, which is commonly used in a day's blasting, does not do so much harm in this way as by the sulphide or sulphate of potassium it produces. One blast (4 oz.) gives 713 grains of these compounds, which, mingled with the confined air, renders it intolerable to breathe for a time. There are, besides, numerous other deleterious compounds resulting from the burning of gunpowder.

Wehrle describes as follows the different degrees of impurity in the air of mines:

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[1] *I. e., per cent.;* equal to 5.0 parts per 10,000.

[2] R. A. Smith: L. c., p. 78.

[3] Brockmann: Die metallurg. Krankheiten.

[4] Annales de chim. et de phys., 1841.

"That air in which the mining-candle burns dull and dark, but in which the workman feels no oppression, is called (matte Luft) dull, flat, or stale air. But when the workman cannot keep his candle burning, it is called bad air (schlechte Lüfte or Wetter). A man may live in this bad air, and an Argand lamp may burn in it; but when this also goes out, and the workman feels confined (beengt), or when he is suffocated, then it is bad or poisonous air (Schwaden). When the quantity of oxygen falls under 13 per cent., and is too small for the process of respiration, or when the carbonic acid amounts to 7 per cent., with several per cent. of sulphuretted hydrogen and miasmas of a peculiar kind, they communicate to the atmospheric air a property which is often very dangerous."

The amount of carbonic acid allowable in air for respiration is given differently. Leblanc named, as the maximum allowable, 5 parts per thousand by measure; Poumet, 2–3 parts; Wolpert, 2 parts. But in later times the authority of Pettenkofer has replaced these statements by the more strict claim that 7 parts per ten thousand is the maximum to be allowed in the air of dwellings. De Chaumont gives 6 in 10,000. Pettenkofer states that "air is bad, and improper for continuous use, when it contains, in consequence of respiration and perspiration, more than 1 part of CO_2 in 1,000; and a *good* air for chambers, in which a person may remain for a long time in a state of health and comfort, contains no more than 0.7 of a part in 1,000, or 7 parts in 10,000."

These statements must all be qualified by the implied condition that the carbonic acid is derived from respiration. The poisonous element in badly ventilated places is now fully understood to consist, not of carbonic acid, but of the organic compounds which are given off simultaneously from the lungs and skin; and the value of analyses of air, contaminated by human exhalations, consists in the probability that the proportion of these organic compounds in a given specimen is fairly represented by the proportion of CO_2.[1] These organic effluvia will be spoken of again.

Air which is changed rapidly may be permitted, perhaps, to contain a relatively larger proportion of CO_2. In certain situations, where the cubic space is very small and the number of persons large, even rapid change does not lower the proportion to what might be desired in large rooms; but it is quite possible that the element of rapidity of change may have its special effect in purifying the air, by preventing the organic ingredients from having time to decay. Investigations into the air of railway carriages, made by Lang and others, have shown that the air may be considered pure and good as long as it does not contain more than 10 parts per 10,000 of CO_2; and an amount not exceeding 15 parts may be permissible in such places.

It has been thought that a very large room may contain so much air

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[1] "From experiments made at Gravesend, Netley, Aldershot, and Hilsea, by various medical officers (De Chaumont, Hewlett, and others), it has been shown that the amount of potassium permanganate destroyed by air drawn through its solution is generally in proportion to the amount of carbonic acid of respiration." (Parkes' Hygiene.)

as to require little or no ventilation. Such a case can hardly be admitted. Practically speaking, a room of ordinary size, or even a hospital ward, is not the gainer by being made more than thirteen feet high. Indeed, the existence of abundant *space* may tempt us to neglect the necessity of abundant *renewal*, and so a large room be more unsafe than a small one. The only advantage of great space lies in the fact that we can *ventilate freely without giving rise to perceptible draught.*

In respect to the minuteness with which we ought to carry out the analysis for CO_2, R. A. Smith makes these remarks :[1]

"A very minute amount of carbonic acid shows deterioration of air sufficient for the senses to observe. The senses observe a difference between Manchester and the outskirts. The difference is .0034 *per cent.* [or 0.34 per 10,000]. The senses observe it in London, where the difference between the streets and parks is .0040 *per cent.* . . . The conclusion is, that carbonic acid in these small amounts is not that which annoys us. In some towns it is no doubt sulphurous acid; in others organic matter and gases from putrefaction.

"It does not follow that we must therefore neglect carbonic acid; on the contrary, it ought to be examined minutely, so that not the smallest increase be allowed, if possible; not that we know certainly of any positive evil which it can do of itself in these small quantities, but because it almost always comes in bad company.

"In the above analyses the air containing .0774 [7.74 per 10,000] is really worse than that containing .1604, and even .3 [16. and 30.], because over the middens [the former] there is a little sulphuretted hydrogen. It is well, then, in such cases to use a double test. Indeed it is probable enough that other gases besides sulphuretted hydrogen, such as marsh gas and hydrogen—products of decomposition—are issuing from cesspools and middens. I should not say probable; it is really certain. These gases, including the carbonic acid, show the reason why less oxygen should be found in such places.

"A deviation of .02 [= 2 parts in 10,000] is not pleasant to us when it is caused by simple want of ventilation. If it is accompanied with gases of putrefaction, it is much more hurtful, as some of these are very deadly.

"We must not conclude that, because the quantity of carbonic acid is small, the effect is small; the conclusion is rather that minute changes in the amount of this acid are indications of occurrences of the highest importance.

"In the case of carbonic acid, we must attend to the third place even now, as I believe, and for scientific purposes even to the fourth, or one in a million. . . . Let us consider what is meant by a difference between .0314 per cent. and .0400 per cent., or 86 in a million. A room twice the size of one not unusual, or two 30 feet long, 24 feet wide, and 15 high, will contain 21,600 cubic feet. If we introduce .0086 per cent., we bring

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[1] Air and Rain, p. 55.

3,200 cubic inches of carbonic acid into the room, or nearly 12 gallons. If we take the numbers found in a very moderately close building, we add 1,239 in a million, or 168 gallons. If we make the room as close as in a crowded theatre, taking the number given for one in London .320, we add 2,831 in a million, or 377 gallons. In order to read off the amount in a million, there ought always to be four figures after the decimal point [*i. e.*, when the number of parts in 100 of air is given]."

Pure carbonic acid is not *proved* to be injurious in quantities slightly exceeding the normal rates of 3 or 4 per 10,000 parts. It proves nothing against the salubrity of Munich, for instance, that the air contains a general average of .05 per cent. (if we accept the figures), nearly one-fourth more than that of London. The cause of the presence of carbonic acid must be looked to before we are sure that it is an index of pollution. Munich lies 1,690 feet above the sea, and may share in the excess of CO_2, common to many elevated spots with pure atmosphere. In cases where the atmosphere is loaded with a pure carbonic acid—as by the accidental escape of the gas where soda-fountains are being charged—it is not found that the slightest inconvenience or annoyance is felt by those who work in such air, although containing in some cases nearly 2 per cent. of the gas.

Pettenkofer has passed some hours in air containing 10 per mille CO_2, without affecting his comfort.[1]

Förster states that during a stay of ten minutes in a cellar containing fermenting wine, with a proportion of 40 per mille of CO_2 in the air, he felt no difficulty in breathing.[2]

There is a vast difference when the carbonic acid originates in the breath. Smith, for instance, after making the experiment, says: "It seems to me impossible to endure 4 per cent. for any length of time."

We cannot affirm, therefore, that carbonic acid is proved directly poisonous in small quantities, or even (in milder terms) that it is injurious. It is, however, well to bear in mind that the pure gas destroys life, as water puts out a candle. And that it may be suddenly dangerous in quantities which often occur in foul places in mines, is shown by the following anecdote, given by Smith.[3]

A young lady was anxious to be in the closed chamber (described hereafter), when the amount of CO_2 was sufficient to put out the candles. She entered when the candles were threatening to go out, so that there could not be quite 19 per cent. of oxygen with 2.1 of carbonic acid. No one had been breathing in it, so that the organic matter from the poison was absent. She stood five minutes perfectly well, and making light of the difficulty, but suddenly became white and could not come out without help. She was remarkably healthy, never was ill, and was troubled with no fear of the air in which she stood.

In another experiment with the closed chamber, candles were burned

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[1] Annalen der Chemie und Pharmacie, 1862, Suppl., Bd. II.

[2] Zeitschrift f. Biologie, Bd. XI.

[3] L. c., p. 441.

until they went out. Smith and others then entered. "We breathed without difficulty at first, but a gradual feeling of discomfort appeared of a kind which is not easily described ; it was restlessness and anxiety without pain, whilst the breathing increased in rapidity. Afterward gas was lighted, and burned with brilliancy. On entering after the gas had gone out, candles were extinguished as rapidly and completely as if they had been thrust into water ; nevertheless we still breathed, and although every one was anxious to go out, no very correct description of the feelings could be given. I stood on a chair, and then a feeling of incipient fainting began ; but the senses were not annoyed by anything beyond a feeling of closeness, by no means so unpleasant as a school-room or close end (in a mine). This is a very important fact, as it points again to the organic matter, of which there was little here, and of which there is much in a school-room or close-end. The lungs seemed to refuse expansion, without the senses being able to indicate a reason. The actual amount of oxygen when the gas went out is not known ; but a specimen, taken from the room after the door had been opened long enough to allow three persons to enter, contained 17.45 per cent."

"On another occasion a still greater amount of carbonic acid was present in the chamber, but it was not accompanied with a corresponding loss of oxygen, as the gas was driven in upon pure air. The oxygen, therefore, was 20.19 with 3.84 of carbonic acid [= 96 times the normal percentage]. On this occasion, Dr. Reissig and Mr. Higgins got headaches instantaneously on entering, and were unable to stay above seven or eight minutes. I stayed about twenty minutes, still felt very anxious to get out, as all my movements were made with great haste, and both mind and body betrayed symptoms of feverish activity. There was also a rush of blood to the head, the face was flushed, and the lungs acted more rapidly than usual, the inspirations being 26, whilst the average of waking hours was as nearly as possible 20. . . . I was satisfied that the condition of body and mind was caused entirely by physical agents, not by the imagination. There was a burning haste to live, as if life were afraid of being put out."

With these statements may be compared those of M. Foster (Handbook of Physiology). "When an animal is made to breathe an atmosphere containing an excess of carbonic acid, in the presence of an ample supply of oxygen, the breathing becomes labored, the respiratory movements being deeper and more frequent. True dyspnœa, however, does not set in, and death does not take place by convulsions and asphyxia [as is the case in deprivation of oxygen] ; the symptoms, on the contrary, resemble those of an animal under the influence of a narcotic poison, such as opium."

A dog, in an atmosphere of CO_2 $9\frac{3}{4}$ per cent., and oxygen $4\frac{1}{2}$ per cent., fell into a deathlike coma, but recovered soon in pure air, and in thirty minutes was as lively as before. This is a mixed result.

There is also evidence that simple lessening of the amount of oxygen in the air has a decidedly injurious effect. It is palpably so in the effect it has on the burning of a candle. R. A. Smith found that a candle rapidly went out in air containing 2.2 per cent. of carbonic acid, replacing a corresponding amount of oxygen; when the carbonic acid was washed out from this air, and the oxygen formed 18.5 per cent., the candle burned, but with a photometric value of 45, as against 75 in pure air. At the same time, a great relief to breathing was felt on the simple removal of the carbonic acid.

"In an atmosphere poor in oxygen there is felt—not so much as a consequence of the presence of nitrogen, as of the absence of oxygen—contraction of the chest, tickling of the eyes, fatigue, weakness, and anxiety; we breathe more heavily and frequently, and are compelled to make more exertion at work, while perspiration and thirst ensue." (Wehrle.)

Under ordinary circumstances, deprivation of oxygenated air cannot be endured by man for more than two or three minutes. Those men who dive for sponges in the Mediterranean [1] probably carry this endurance as far as any; the usual duration of the dive is two minutes, and three and a half is its utmost extent. It is known to physiologists that an increased amount of oxygen can be introduced into the blood by simply accelerating the breathing, without altering the depth of inhalation. Putting this principle into practice, "the diver, standing naked in the boat, with the greatest earnestness practises inflating his chest to the utmost for about ten minutes, and, when the blood is thoroughly oxygenated by this means, seizes the stone, and plunges headlong into the sea. When he is at a great depth, he often remains until he feels the sensation of drowning, the desire to sleep. Alarmed by this last symptom of exhausted nature, he jerks the rope, and is hastily pulled to the surface by his companions in the boat above; if he loses the rope, he is usually too heavily weighted with sponges, and is drowned. The return to the surface, where the pressure is so much reduced, causes the blood to flow from mouth, nostrils, and eyes; and this, and the absence of normal respiration for so long a time, brings on a fainting-fit, which lasts, according to the depth, for a shorter or longer time."

The sensible effects of an atmosphere which is gradually becoming polluted by the human breath and perspiration are well described by R. A. Smith, from whom the following is extracted. The experiment was made in a closed chamber of lead, containing (allowing for one person and a chair and table) 170 cubic feet of air:

"The first trial of the chamber was made by simply sitting down for an hour and forty minutes. This produces about one per cent. of carbonic acid. The day was clear and the air pleasant; the temperature 45° F. No difference was, to a certainty, perceptible for twenty-five minutes. Then, when the air was drawn from the top by means of an umbrella, it seemed like a soft wind, and had, to some extent, a pleasant

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[1] A. Hyatt: Guides to Science-teaching, No. III., published by the Boston Society of Natural History, 1879.

feeling, but was entirely devoid of a faculty of cheering. A dull, cheerless air is well known. Here we had it produced at once. The air was very moist, and deposited water when drawn out through a tube on taking a specimen. After an hour the unpleasant smell of organic matter, such as is so well known in a crowded school, was perceptible on stepping rapidly from one end to the other, or on moving the air rapidly. Here we learn that when a current of air blows on us the chemical actions accumulate, and, although if continued for one instant only, they may be imperceptible, if repeated for many, they culminate in a sensation. . . . If the chemical action began at the first so violently as to produce decided sensations, he might be able to avoid it at once before it produces any abiding impression. For this reason a bad climate is more dangerous than the fumes of vitriol, when we are at all able to move out of the way."

"It was very decidedly perceived, after remaining an hour, that the air was soft when made to move in this chamber. This arose from the moisture, and shows us at least that a soft air may be a very impure one. Soft air, air with a good deal of vapor, is very soothing; it calms the mind and the body and [checks] the burning of a candle or a fire. In this state it cannot be very cold, as the warmth is essential to the existence of the vapor. This air has a tendency to leave the skin and its action unchanged; it causes little evaporation; and perhaps an influence is due to this, that the amount of oxygen introduced into the lungs is diminished, whilst no injurious ingredient is added. I think I hear the question, Will not the air in the lungs decide for itself at once how much vapor there shall be, as there is such an abundant moist surface? The entrances to the lungs—that is, the nostrils and the mouth—feel the moisture with great clearness; and when the air is dry they are dried up. But the lungs seem to feel it also; and it seems a common thing to know the difference in the respiration. Dry air stimulates the skin, because it removes the moisture; and the skin must set to work to renew it. Dry air, therefore, would in this respect be in its first action cheering, and in its last irritating. Moist air would, from this point of view, be calming in its action, and often at once calming to languor, probably preservative of the vital powers which are not frittered away by a constant irritation. I speak only as a chemist.

"After staying in the chamber for 100 minutes, the air had an unpleasant flavor or smell, and I came out; three persons entered at once, and pronounced it very bad; I entered after a minute, and found it very bad. It seemed to me, however, that we are frequently exposed to air equally bad, although I have not found any in daily life so much deprived of oxygen as this must have been, reduced, that is, to twenty per cent.

"I was extremely glad of the escape from this impure air; this gladness not arising from any previous discomfort. I was not uncomfortable. I chose that time of coming out, as it was the moment when the organic matter was most distinctly perceptible; still, to perceive it when quiet required attention. The pleasure on coming out was one wholly unexpected; although I now recognize it as exactly that which one has when walking home on a fine evening after leaving a room which has been crowded—it was the reassertion of the rights of oxidation; the blood was evidently in active change desirous to take up a position that was lost, else why was this feeling of unusual delight in the mere act of breathing, which feeling continued for four hours? Dinner seems to have first removed it. From the long time required to bring the functions of breathing to their former state, we may of course argue that they had been much disturbed. . . . In about four hours the lungs recovered their tone. By the tone is meant their unconscious working. Food seemed to be more than usually required, and was followed with unusual rapidity by the feeling of refreshment. Now, as there was no unusual bodily exertion, the demand could not arise from an unusual wear of the system, and indeed the peculiar feeling was rather a need of support than actual hunger demanding food."

In other experiments upon persons sitting in the hermetically closed room, Smith found that "carbonic acid and other emanations from the person diminish the circulation, and hasten the respiration, and that the effect is perceptible in a very short time, when the percentage of carbonic acid reaches .18 [= 18 in 10,000], or say one-fifth of a per cent. certainly. If, however, we do not wish to infer too much from one beat of the pulse, let us, for rough practice, say ¼ per cent. We may infer also that smaller quantities will show their consequences after a longer time."

The result of continued breathing of air in confined spaces is well known to be fatal after a certain time. In the year 1846, a large number of English troops perished thus on board of the transport "Maria Somes," having been confined below hatches during a storm, without fresh air. Two hundred passengers on the English steamer "Londonderry," in 1848, were confined in so small a space that each person had scarcely four cubic feet of air; of these, seventy-two died. The "Black Hole" of Calcutta has passed into a proverb.

The symptoms, systematically analyzed, of such poisoning are as follows (Eulenberg):

1st stage: Oppression in breathing and anxious restlessness. In many persons the first symptoms are giddiness, noise in the ears, photopsia. Confusion and oppression of the head increase until the person cannot stand. Sometimes with this there is associated a kind of hilarious intoxication with hasty speech and restless gestures, which may give place to heavy sleep when the person is recovering.

2d stage: Spasms. These are not usually so characteristic as in the case of carbonic oxide.

3d stage: Asphyxia.

4th stage: If removed from the bad air, recovery occurs speedily and perfectly. Miners, however, observe certain after-symptoms, including gastric disturbances, headache, photopsia and ringing in the ears.

"When air more moderately vitiated by respiration is breathed for a longer period, and continuously, its effects become complicated with those of other conditions. Usually a person who is compelled to breathe such an atmosphere is, at the same time, sedentary, and, perhaps, remains in a constrained position for several hours, or possibly is also under-fed or intemperate. But allowing the fullest effect to all other agencies, there is no doubt that the breathing the vitiated atmosphere of respiration has a most injurious effect on the health. Persons soon become pale, and partially lose their appetite, and after a time decline in muscular strength and spirits. The aëration and nutrition of the blood seem to be interfered with, and the general tone of the system falls below par. Of special diseases it appears pretty clear that pulmonary affections are more common." (Parkes: Manual of Practical Hygiene.)

Transfer of oxygen to the system, and excretion of carbonic acid.—This is effected in the act of respiration. The air parts with oxygen, which by the usual process of endosmosis passes through the walls of the pulmonary vesicles and the capillaries to the red corpuscles, in which it enters into a loose combination with the hæmoglobin, in the proportion of 1.76 c.c. to 1 grm. of the latter. By an equally facile change, the gas is given off to the tissues of the body in exchange for carbonic acid. The deadly effects of carbonic oxide are due to the fact that it combines with the hæmoglobin with such eagerness as almost to prevent the oxygen from entering into combination when inhaled, even after the poison has been removed from the air. It "paralyzes" the red blood-corpuscles (Bernard), and the result is death by suffocation. The relief of asphyxia by carbonic oxide is effected in the same way as in the case of drowning, viz., by artificial respiration, whereby successive though small quantities of oxygen are introduced into the system, until the poison is eliminated.

Sulphuretted hydrogen produces effects resembling those of carbonic acid, but in a different manner; it acts as a reducing agent.

"It is believed that the blood-corpuscles possess the power of ozonizing the oxygen inhaled, peroxide of hydrogen being formed by its combination with water. This compound is again decomposed into water and oxygen, which oxygen in its nascent state serves for the purposes of oxidation (of tissue). It is certain that both blood and hæmoglobin have the power of setting free the oxygen absorbed by oil of turpentine, and that blood-globules act similarly on peroxide of hydrogen. The nascent oxygen thus evolved is capable of acting on such bodies as potassic iodide and starch, tincture of guaiacum, etc. In fact, Schönbein taught that the function of the blood-corpuscles was the chemical excitement of the oxygen of the respired air. If hæmoglobin be mixed with alcohol or heated to 212° F., it then loses the power of decomposing the peroxide. Thus it is held that there is perpetually going on, in the animal organism, the formation and destruction of ozone and peroxide of hydrogen. The solution of the corpuscles and their alteration into other products is believed to be due to the ozone. These products have no longer any plastic property, and in this way Schmidt believes that the fluidity of blood is maintained. (Schönbein, Schmidt, Schreiber, etc.)[1]" These statements may be considered as questionable.

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[1] C. Meymott Tidy, l. c.

It would appear that the injurious effects of carbonic acid in respired air are due to the fact that, for purely physical reasons, it lessens the exchange of carbonic acid for oxygen, in the red globules. It does not do this by pre-occupying the latter, for it seems to be held in solution in the entire blood or in the serum, indifferently, and under the general laws of solution; and as soon as a pure air is supplied, it is ready to pass off at once. The addition of oxygen in excess, furthermore, counteracts an excess of carbonic acid. Regnault and Reiset found that animals, in air containing one and a half or two times the ordinary proportion of oxygen, even if the carbonic acid equalled 17–23 per cent. of the air, suffered no injury after the lapse of 22–26 hours.

The effects of inhalation of carbonic oxide are described as follows by Eulenberg:

1st stage: Stupefaction. Sometimes begins with great restlessness, increased breathing, accelerated beat of the heart, followed in animals by giddiness, tottering gait, and tendency to fall. Sometimes the animal picks himself up again; at last he is unable to do so.

2d stage: Convulsions. These are very frequent, and are only absent when the quantity inhaled is very small and the period protracted. They may be partial or general.

3d stage: Asphyxia, which comes on with a rapidity proportioned to the dose.

The chemist Chenot, having accidentally inhaled a single breath of gas, fell on his back to the ground as if struck by lightning; his eyes were rolled in their sockets, and his extremities drawn up. In a quarter of an hour, external sensation returned, with a feeling of cold and suffocation. A heavy sweat covered his whole body; while a peculiar hyperæsthesia of the brain existed.

Carbonic oxide is known to be often present in minute quantities in the air of inhabited rooms, proceeding from defects in furnaces or stoves, and to some extent from the imperfect combustion of illuminating material. Being a frequent ingredient of illuminating gas, it may enter a room through a leak, or through the sides of flexible tubes. It has been found in tobacco-smoke. Many people suffer from small amounts; the effects commonly attributed to its action in ordinary life are, giddiness, headache, and prostration of strength. It exists in the smoke of a glowing candle-wick. Death occasionally results from the careless use of braziers containing charcoal, so commonly used in Southern Europe: King Alfonso very nearly lost his life from this cause, a few years ago, in Spain. The danger of closing the chimney-draught of a stove arises chiefly from the probability that quantities of this gas will be thrown back into the room. The fuel (anthracite, wood, coke, charcoal, soft-coal), which burns readily and without carbonic oxide while abundant fresh air is supplied, gives rise, when the draught is checked, to the half-oxidized product (CO instead of CO_2). In no case can we say that a given fire produces no carbonic oxide. For example, in a bed of live coals, ten inches deep, we know that it exists in abundance in the central layers, where oxygen is deficient in amount; it issues in quantities from the upper layer, where, again meeting with air, it becomes further oxidized or burnt, making a blue or yellowish flame, characteristic of the perfect combustion of anthracite and charcoal, and forming carbonic acid.

The best method of determining the amount of carbonic acid in the air is that of Pettenkofer, as given in Lange (Ueber natürliche Ventilation) and in Parkes' Hygiene, originally in Pettenkofer (Ueber Lüftung und Heizung von Eisenbahnwagen); also in Wolffhügel: Ueber die Prüfung von Ventilations-Apparaten. The process consists in absorption of the carbonic acid, contained in a bottle of given size filled with the air to be tested, by the hydroxide of an alkaline earth, and titration with oxalic acid. Lime-water may be used, but baryta-water is preferable. A more simple method, however, is desirable, and will be here described, being sufficient to determine with tolerable accuracy the number of parts in 10,000 without fractions. It is given as proposed by Lange:

The test depends firstly on the fact that carbonic acid, in lime-water or baryta-water, causes a precipitate of carbonate of lime or barium, which becomes manifest by turbidity of the solution, previously clear; and, secondly, that the eye does not perceive this turbidity until it has reached a certain point—which may vary with different observers, but may be established by each one, arbitrarily, for himself. The richer the air in carbonic acid, the less air will be required to impart a distinct turbidity to a definite quantity of baryta-water. In making the test he uses six bottles, containing respectively 450, 350, 300, 250, 200, and 150 c.c. The bottles being made perfectly clean and dry, 15 c.c. of clear fresh lime-water is put into the smallest, the cork replaced, and the bottle well shaken. We next observe whether a turbidity has appeared; if not, we take the next larger bottle, go through the same process, and so on, until a bottle is found in which a distinct turbidity appears. It is well to acquire by previous experiment a notion of the appearance of a fluid which is just becoming turbid; this can easily be done by performing the experiment repeatedly in the open air, in the garden, etc., where the air contains just enough to give rise to the appearance. Such air will contain say 4 or 5 volumes of carbonic acid in 10,000; certainly not so much as 6.[1] The air of a chamber will rarely be as pure as that; we must be content if we have to use the second bottle (of 350 c.c.), before opacity occurs; the air will then contain about 7 of carbonic acid to 10,000, and we may perhaps be content with even the third (300 c.c.), which indicates 8 parts. But if the fourth (250 c.c.) is made turbid, an amount of nearly 10 in 10,000 is indicated; the fifth (200 c.c.) shows 12, and if the sixth and smallest (150 c.c.) should be made turbid, there are at least 16 volumes of carbonic acid in 10,000 of air, which renders it needless to employ smaller bottles. A small piece of paper, marked on the inside with a cross in lead-pencil, may be gummed to the side of the bottle at the lower part; the fact of

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[1] But compare De Chaumont's table, p. 613.

turbidness may be judged of by the cross becoming invisible when looked at through the water.

Another method requires the use of only one bottle, of the size of 50 c.c., with a cork pierced by two glass tubes. Seven centimetres of baryta-water (6 grms. to the litre) are put into the bottle, and successive charges of air are sucked through the fluid by means of a rubber-tube and ball-syringe of known size (which gives 23 c.c. of air when pressed). At every successive introduction of air into the bottle, the latter is shaken to cause the contained carbonic acid to combine with the baryta. The gradations observed are finer than in the other method, being as follows (beginning at the second charge): 22, 17.6, 14.8, 12.6, 11, 9.8, 8.8, 8.0, 7.4, 6.8, 6.3, 5.8, 5.4, 5.1, 4.9 parts per 10,000. The method is given with details by Lange, op. cit. It may be better to introduce the air by an aspirator, which is a tin box of water, with a tube at the top, which can be connected with the bottle; when a cock at the bottom of the box is turned, a measured amount of water escaping will suck an equivalent amount through the bottle.

The presence of carbonic oxide in the air may be recognized by the spectroscopic test, as given by H. W. Vogel.[1] The following is quoted from Lange: "A bottle of about 100 c.c. capacity, filled with water, is emptied in the room of which the air is to be tested; then 2 or 3 c.c. of water, containing blood, are poured into the bottle. The amount of blood should be just sufficient to impart a tinge of red, but should give the well-known absorption-band in the spectroscope, when held in a test-tube of 1.8 to 2 ctm. in thickness. If this solution be shaken in the bottle for a minute, any carbonic oxide that may be present will demonstrate its existence by changing the color of the blood, which will become of a stronger red (rosa). The absorption-bands, at the same time, are a little paler, more obliterated, and a little further to the left, than in pure blood. These appearances are enough to determine, for a skilled spectroscopic analyst, the presence of CO; but those less experienced may satisfy themselves by adding three or four drops of strong sulphuret of ammonium, which makes the two lines disappear in blood which is free from carbonic oxide, their places being supplied by a broad, pale (verwaschen) shadow; while the bands in blood impregnated with carbonic oxide are unaffected by sulphuret of ammonium."

Kühne[2] states that carbonic oxide-gas, combined with hæmoglobin, causes the absorption-band α to move toward the line E of Frauenhofer: blood containing this element is not darkened by any of the reducing agents, and the bands α and β remain without the appearance of the shadow γ.

Böttcher's reaction[3] for carbonic oxide depends on the production of a black color in a strip of linen or cotton cloth, first saturated with a

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[1] Berichte der deutschen chemischen Gesellschaft, 1877, No. 8, p. 792.

[2] Lehrbuch der physiologischen Chemie, 1868.

[3] Journ. für prakt. Chemie, Bd. 76, pp. 233 and 234.

moderately concentrated solution of chloride of palladium, then superficially dried between blotting-paper, and then exposed to the air to be tested. The blacking should appear within a few minutes. Gottschalk[1] has modified this; he uses sodio-chloride of palladium, and passes the air by aspiration through a solution of the salt.

MISCELLANEOUS IMPURITIES IN THE AIR.

This part of the subject is by no means free from complexity. The number of substances already known to exist, in various ways, in the air, is very great. Some of them are found in a form and under circumstances which enable us to state that their origin is inorganic; such, for instance, are the chloride of sodium and other salts, found in the purest sea-air. Others, though composed of the same (inorganic) elements, are traceable to the decomposition or combustion of organic matter; such are the chlorides and sulphates found near large cities. In fact, the changes undergone in the air by many substances are so rapid, that it is not possible to classify them strictly by reference to their origin. We shall, therefore, first enumerate the substances found in air, according to their condition, as solid, gaseous, or in solution.

Solid Impurities.

Foreign ingredients in the solid form are brought into the air in various ways. As dust, they are taken up from the soil by the wind, and are thus often transported for hundreds of miles. African organisms have been found in the air of Berlin. In certain parts of the world, the prevalence of winds in a given direction for long periods has effected a change in the natural features of the landscape, and has produced a stratified deposit of great thickness (loess), ascribed to the accumulation of solid particles conveyed by the wind from distant plains. Depositing its burden of dust, the air in process of time fills up the valleys, and converts the country into a nearly level plain, rising gently to the central continental elevation. Such an origin is ascribed to the great plains which extend from the Mississippi to the Rocky Mountains, and to the steppes of China and Central Asia (Von Richthofen).

The discharge from volcanoes, as is well known, may also travel several hundreds of miles through upper strata of air, finally appearing on the surface of the earth as showers of dust.

The débris of vegetation, in a pulverulent state, occurs in large amounts in the air, and both animal and vegetable organisms abound. It is next to impossible to obtain air that is quite free from some of this class of impurity.

The injury inflicted on the system by these substances is difficult to state ; but, while we know the desirableness of pure air, we must also

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[1] Ueber die Nachweisbarkeit des Kohlenoxydes, 1877.

admit that a moderate amount of mineral impurity of a neutral sort is borne without manifest injury. Of the injury received by inhaling certain special matters—carbon, arsenic (arseniuretted hydrogen ?), lead, antimony, and other poisonous or irritating substances in powder,—an account will be given in another part of this work, under Diseases of Occupation.

Among the substances found in dust, are to be named silica, silicate of alumina, carbonate and phosphate of lime, peroxide of iron, and other minerals, from the soil, in an unchanged condition. Particles of iron stripped or rubbed from the rails, may be detected in the air of a railroad-train. Paint, cement, ashes, stone-dust, shell-dust, and various metals in a minutely subdivided form, may be similarly found in certain workshops and offices, giving rise to a variety of special diseases.

From the burning of soft coal come large quantities of tar and soot, estimated by Smith to equal one per cent. of the weight of the fuel. These are very slow in passing off, being too heavy to rise high or drift far. As a rule (Parkes), the particles of carbon are not found higher than 600 feet.

The animal and vegetable kingdoms furnish a great variety of material for "dust."

Among these may be mentioned certain minute animals, that live in the air, or may have been lifted from the surface of the water by the ascensional force of evaporation. Fragments of insects are found. Ehrenberg has discovered individuals of the rhizopods, tardigrades, and anguillulæ, which, when dried, retain their vitality for months and years; and in dust-showers he has found some hundreds of forms, classed as polygastrica, phytolithariæ, etc.

Bacteria, vibriones, and monads, are found very frequently.

From the vegetable kingdom come the seeds and débris of vegetation; pollen, cuticular scales, vegetable fibres and hairs, seed-capsules, globular cells, etc., etc.; the spores, rarely the mycelium, of fungi; mycoderms and mucedines, volatile substances and odors, the cells of protococcus pluviatilis, and perhaps of other algæ. And of the lowest orders of life we find diatoms and living infusoria, and those extremely minute and oval cells, probably growing by cleavage, called microzymes.

The air of streets often contains considerable quantities of vegetable fibre from horse-droppings.

In enclosed spaces, where many persons are living, we may find scaly epithelium, round cells resembling nuclei, animal and vegetable fibres (wool and cotton), starch, and other elements of food, hair, wood, coal, pus-globules, fatty crystals, and bacteria, both free and in the zoöglœal form. Under more special conditions we find—in skin-wards, achorion, the spores and mycelium of trichophyton, variolous corpuscles; in phthisical wards, cells like those seen in tuberculous matter (Watson).

Some amorphous substances may be the remains of animal bodies or animal discharges.

The power of vital resistance possessed by certain low organisms is most remarkable. Messrs. Dallinger and Drysdale[1] have found that the sporules of certain cercomonads resist an exposure to a dry heat above that of boiling water, in one case retaining life at 250° F., in another at 300° F. These germs are of excessive minuteness, not exceeding $\frac{1}{200000}$ of an inch in diameter. In repeating the experiments a few years subsequently,[2] a similar result was reached; the spores of a certain form of cercomonad lived at 248° dry heat, and 220° moist heat; the adult forms were killed at 142°.

According to Carpenter[3] the rotifers, tardigrades, and anguillulæ possess the power of revival after desiccation for however remote a time.

Petit[4] has found that diatoms, collected with the soil which bore them, and allowed to dry under exposure to the sun for six and eight months, preserved their vegetative power. It seemed to be necessary, however, that the drying should be gradual, as is the case in nature.

These statements will remind the reader of the application which Tyndall and others have made of our knowledge of minute organisms, in establishing a "germ theory" of disease. Tyndall[5] holds that the passage of a powerful beam of light through air is the best, if not the only absolute test, for showing the presence of minute particles, such, for example, as the spores previously mentioned, which would almost certainly have eluded microscopical search if they had not been watched for in the act of escaping from the parent cell. The motes in the air are what render the beam of light visible; and when air is allowed to purify itself by simple rest, giving the motes time to settle and adhere to the bottom and sides of the containing vessel, it is found that the beam ceases to be visible. It is also found that air thus purified, by standing three or four days, no longer possesses the power of exciting putrefaction in infusions of animal and vegetable substances previously heated to a sufficient degree.

The bearings of this discovery, and, in fact, of the whole controversy concerning "spontaneous generation," are obvious. Lister has made the practical inference that by exclusion of germs from the large surfaces left after amputations, the health and rapid union of the parts can be secured; he attains his object by operating in a cloud of the vapor of carbolic acid and by the purification of all his instruments and appliances from germs.

Tyndall, assisted by a number of coadjutors, experimented upon the effect which exposure to the air has in setting up the process of decomposition in animal infusions or broths. In these experiments different series of test-tubes were exposed in various places, in different towns. In all that were exposed to the air, before the latter had been purified by

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[1] Monthly Microscopical Journal, Vols. X. and XI.

[2] Proceedings of the Royal Society, No. 187, 1878. American Journal of Microscopy, Vol. III., No. 8.

[3] The Microscope and its Revelations.

[4] American Journal of Microscopy, Vol. III., No. 4.

[5] On the Optical Deportment of the Atmosphere in Reference to the Phenomena of Putrefaction and Infection. Abstract of a paper read before the Royal Society, January 13, 1876, by Prof. Tyndall, F.R.S. American Journal Microscopy, Vol. I., No. 4.

settling, there were found bacteria, or penicillium. As a general rule, those exposed during the autumn remained for two days or more perfectly clear. Doubtless from the first, germs fell into them, but they required time to be hatched. This period of clearness may be called the "period of latency," and, indeed, it exactly corresponds with what is understood by this term in medicine. Toward the end of this period of latency, the fall into a state of disease is comparatively sudden, the infusion passing from perfect clearness to cloudiness more or less dense in a few hours.

Another remarkable point is the inequality with which different test-tubes (in a series of 100 exposed at once, side by side) seem to be attacked by these germs. In one experiment, on the third day, twenty-seven tubes had been attacked, scattered at various points in the set. On the next day all were attacked, but the differences in their contents were extraordinary. All of them contained bacteria, some few others in swarms. In some tubes they were slow and sickly in their motions, in some apparently dead, while in others they darted about with rampant vigor. These differences are to be referred to changes in the germinal matter, for the same infusion was presented everywhere to the air. Here, also, we have a picture of what occurs during an epidemic. The air which communicates infection to the test-tubes may be supposed to contain the germs, not in uniform diffusion, but in masses which may be compared to clouds. Ehrenberg,[1] in 1838, made the same comparison. The air which conveys the infection of fevers or of gangrene may be similarly presumed to contain, now great quantities, and now scarcely any, of the organisms in question ; and in a room containing the infection, a portion of the air may be loaded, while other portions are nearly free, which would explain anomalous cases of escape from septic or zymotic influences.

Gaseous Impurities.

The following gaseous compounds, found as impurities in the air, are mentioned by Parkes:

Of carbon.—Carbonic acid (abnormal if exceeding 5 in 10,000 parts), carbonic oxide, carburetted hydrogen, and peculiar substances (gaseous) in sewer air.

Of sulphur.—Sulphurous acid, sulphuric acid, sulphuretted hydrogen, ammonium sulphide, and carbon bisulphide.

Of chlorine.—Hydrochloric acid from alkali-works.

Of nitrogen.—Ammonia and ammonium acetate, sulphide, and carbonate (normal in small amount ?), and nitrous and nitric acids.

Of phosphorus.—Phosphoretted hydrogen.

Sulphur compounds.—Sulphur exists in most animal substances, and during their decomposition forms sulphuretted hydrogen and sulphide of ammonium. Sulphuretted hydrogen has very few inorganic sources, and, leaving out coal, may be taken as an index of the decomposition of ani-

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[1] Infusions-Thierchen, p. 525.

mal and vegetable matter. When in the air, freely exposed to the contact of oxygen, it becomes sulphuric acid. Sulphide of ammonium in the same circumstances becomes a sulphate, which, encountering common salt (chloride of sodium), produces sulphate of soda and chloride of ammonium. The sulphates form a characteristic ingredient of the air in manufacturing (soft-coal burning) districts.

Nitric acid is produced by the oxygen of the air acting on ammonia, or on the organic substances which contain nitrogen, and are capable of giving out ammonia by their decomposition (Smith). Its amount varies, but in general it increases in the upward direction, and in proportion as that of ammonia diminishes. It probably does no harm, unless present in excessive quantities, and may be considered as one of the most wholesome gaseous forms in which nitrogen and hydrogen pass into the air.

Ammonia is commonly given off during the decomposition of organic substances, unless strong oxidizing influences are present; it appears in combination chiefly as a carbonate or a sulphide. The presence of oxygen, and that of sulphuric acid also, in the air with which it mingles, converts these bodies into sulphate of ammonia, which undergoes a further change upon meeting with chloride of sodium—as was mentioned under sulphur. This ammonia is a sign that decomposition has occurred; it is abundant in foul places, as privies.

Ammonia by itself in minute quantities cannot be classed as a morbific agent. It is not disagreeable to all. But it "has very bad relations, and keeps very bad company; and if it increases so as to be perceptible to the senses, it becomes unpleasant, and of course unwholesome." (Smith.)

The term "albuminoid ammonia" designates that which is obtained from organic substances, either alive, or dead and in decay. An excess in air is a suspicious circumstance; but we cannot always tell to what such excess is due.

The following tables are given by Smith as results of analyses of air from places widely differing in character. The figures are only relative, showing the amount present, as measured by reference to that contained in pure air from Innellan, on the Firth of Clyde, taken at 100:

	Total Ammonia.	Not Albuminoid.	Albuminoid.
Innellan	100	100	100
London	112	117	109
A bed-room	179	194	173
Glasgow	202	150	221
Inside and outside of office	205	235	193
Underground Railway (Metropolitan)	234	138	271
A midden	395	643	301

One of the readiest, though not in all senses the most exact, of tests for the presence of organic matter in air consists in the use of solutions of permanganate of potassium—a salt which readily parts with some of its oxygen to the organic matter, and in doing so loses the rich purple color it possesses even when much diluted. In one respect the test is exact, for we can state the amount of oxygen which has been subtracted; but this does not inform us whether the oxygen has been taken up by sulphurous acid and sulphuretted hydrogen, nitrous acid, tarry matters, etc.; or whether organic matter has been the active agent. In cases where organic matters alone are concerned, the process is one not suited to the use of non-professional persons.

There are several ways of applying the principle. One is to use a bottle of given size, and find the amount of a solution of permanganate (of known strength) that is decomposed by the air contained. Another way is to pass successive volumes of air through a solution, and noting the amount of air required to produce the decomposition; here the impurity of the air will be inversely proportioned to the bulk required. The aspirator may properly be used for this purpose.

However imperfect this method, it certainly yields valuable indications, and with tolerable constancy.

A ready way of pointing out the existence of impurity to unskilled persons is to wash successive volumes of air with the same water. A milkiness is soon observed if the air is impure. With a good country air the test invariably requires many more bottles to produce the impurity in water, than is the case in poor air.

Animal Exhalations.

That these substances probably form an important, though minute, part of the air of close rooms, and also that they are in some way closely connected with watery vapor, seems to be admitted.

Lange states that water collected from the windows of ill-ventilated schools and barracks becomes putrid after standing a short time. In such water are contained the elements which affect our senses unpleasantly when we enter confined places, whether they have been recently occupied, or whether they have been long disused and shut up. Very few, if any, places exist which do not possess their own special odor, perceptible to those who have a fine organization in respect to smell. Whence this odor comes is often extremely hard to decide. It is evident, however, that it may in part be traced to animal deposits on furniture and walls, in carpets, cushions, and curtains. The freshness of a kitchen or hospital ward that is often and well scrubbed proceeds from the frequent removal of surface impurity, whereby the air of the room is brought to a condition resembling that of the outer air. Furniture that has been long neglected, when polished, may be stripped of a dusky glutinous coating. The wood of gymnastic apparatus, and even in school-rooms, if not washed well, has a smell of perspiration highly characteristic.

The sources of this organic deposit are chiefly the perspiration and the breath.

The perspiration contains chloride of sodium and small quantities of other inorganic salts. A small amount of carbonic acid is exhaled in this way: 10 grms. in twenty-four hours, according to Scharling, 4 grms. according to Aubert. Among the substances which give it odor, and which are noxious, are included the following list (and others), viz.: acids of the fatty series, as formic, acetic, butyric, and probably propionic, caproic, and caprylic, and various other volatile acids in small quantity; also, neutral fats, and cholesterin; ammonia (urea), and possibly other nitrogenous bodies. (Foster.) This statement refers only to the condition of health.

In respiration, various impurities in small amount are thrown off, many of which are of an unknown nature. According to Lehmann, such substances as alcohol, phosphorus, camphor, and ethereal oils, which have been taken with the food, are not infrequent in the breath; and even when no such substances can be detected in the food, small quantities of an organic hydrocarbon are found in the expired air. A little ammonia and a good deal of water are also present. But the poisonous ingredients are those whose precise nature is unknown.

The organic matter from the lungs,[1] when drawn through sulphuric acid, darkens it; through permanganate of potash, decolorizes it; and through pure water, renders it offensive. Collected from the air by condensing the watery vapor on the sides of a globe containing ice (as by Taddei in the wards of the Santa Maria Novella), it is found to be precipitated by nitrate of silver, to decolorize potassium permanganate, to blacken on platinum, and to yield ammonia. It is, therefore, nitrogenous and oxydizable. It has a very fœtid smell, and this is retained in a room for so long a time (sometimes for four hours, even when there is free ventilation), as to show that it is oxydized slowly. It is probably in combination with water, as the most hygroscopic substances absorb most of it. It is absorbed most by wool, feathers, damp walls, and moist paper, and least by straw and horse-hair. . . . It is probably not a gas, but is molecular and floats in clouds through the air, as the odor is not always equally diffused through a room. In a room the air of which is at first perfectly pure, but is vitiated by respiration, the smell of organic matter is generally perceptible when the CO_2 reaches 7 per 10,000 parts, and is very strong when it amounts to 10 parts.

From the air of inhabited rooms—and, indeed, from air in general—when drawn through pure water, free ammonia and ammonia in combination with organic bodies (albuminoid ammonia) may be obtained by distillation with alkaline permanganate, in the method of Wanklyn. A series of observations upon the wards of St. Mary's Hospital, by De Chaumont, gave, in milligrammes per cubic metre of air, 0.3519–0.6680 of free NH_3 and 0.4710–0.6915 of albuminoid NH_3, the external air containing 0.3574 and 0.5280 respectively; at another time the wards contained from 0.000 to 0.0497 free, and from 0.2824 to 0.5259 albuminoid, the outer air containing 0.0163 and 0.5206. Smith found in the air of a bed-room, at

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[1] Parkes' Hygiene.

9 P.M., 0.1901, and at 7 A.M., 0.3346 milligrms. to the cubic metre = 83.074 and 146.210 *grains* to a *million cubic feet.*

The animal exhalations in the air of crowded rooms, when condensed upon cold glass, together with the atmospheric vapor, will form, if allowed to stand for some time, a thick, apparently glutinous mass; but, when this is examined by the microscope, it is seen to be a closely-matted confervoid growth, or, in other words, the organic matter is converted into conferva, as it probably would have been converted into any kind of vegetation that happened to take root. Between the stalks of these confervæ are to be seen a number of greenish globules constantly moving about, various species of volvox accompanied also by monads many times smaller. Before this occurs, the odor of perspiration may be distinctly perceived, especially if the vessel containing the liquid be placed in boiling water.

"When this exhalation from animals is condensed on a cold body, it in course of time dries up, and leaves a somewhat glutinous organic plaster; we often see a substance of this nature on the furniture of dirty houses, and in this case there is always a disagreeable smell perceptible."[1]

This substance is organic; it is capable of oxidation, and doubtless undergoes oxidation in the air, forming carbonic acid, water, and ammonia.

In great contrast with these animal organic deposits, stand those of vegetable origin. They were collected in the dew from a flower garden, which was found to present, on boiling down, no disagreeable odor. The small solid residuum, when exposed to heat, had a smell of vegetable matter with very little trace of any nitrogenized substance; it was rather agreeable than otherwise. The dew was beautifully clear and limpid; the condensed vapor from rooms, on the other hand, was thick, oily, and smelling of perspiration.

The escape of odors into the air is facilitated by moisture, as is well known. Moisture seems also to increase the virulence of such animal effluvia as may be connected with the production of certain hospital diseases; for instance, in military ophthalmia, erysipelas, and hospital gangrene. The practice of frequently washing the floors of hospitals is well known to increase the chance of erysipelas (Parkes), and a similar practice on ships is believed to favor the development of pulmonary and zymotic affections. (Th. J. Turner.)

It is remarked by Smith that air soon reaches its point of saturation with the organic vapors of perspiration and breathing.[2] His inference is that their poisonous action does not probably increase, after a certain point, in proportion to the amount of breath discharged into a given volume of air; the excess of these vapors being precipitated in a liquid form on the walls, windows, etc., in the room. It must, however, not be overlooked, that such precipitates are liable to become the source of still worse mischief, by becoming putrid by stagnation in a warm atmos-

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[1] R. A. Smith: Air and Rain.

[2] Pettenkofer: Annalen für Chemie und Pharmacie, 1862. Suppl. Bd.

phere. And such putrescence, indicated by the characteristic sour smell (fresh perspiration not being necessarily offensive), is developed in a very few minutes, either in the air or upon the surface of the body.

In such cases we ought to discountenance the use of perfumes or aromatic fumigations, and to lay all the stress on frequent scrubbing, on free admission of air and sunlight. The first of these measures removes, the second dilutes, the third chemically disinfects, the organic impurities. Cleanliness of the person and clothes is a most important factor in purity of atmosphere; it is very hard, even with abundant means of ventilation, to keep the air of a school-room in a wholesome state if the children are dirty.

Gaseous impurity arises from a variety of decompositions occurring in soil, in rubbish, in animal exhalations and excreta, in dead organic matter generally. Wherever men are massed together, such impurity is likely to exist. It by no means follows, however, that such is an inevitable consequence of crowding. If certain limits are observed, very large and dense populations may retain a fair degree of health, provided that the laws of private cleanliness are observed, and the soil and air protected from public nuisances.

Among the natural agencies by which air is purified, one of the chief consists of the dilution consequent on the process of diffusion. An open vessel full of carbonic acid gas will be found in a few hours to have emptied itself by this process. Currents of air and winds are much more important than diffusion in confined and frequented places. Neither diffusion nor winds, however, effect a purification, strictly speaking; that is accomplished, to a large extent, by re-combinations occurring in the air. by which noxious gases form innocent ones, and also by the agency of rain, which washes out almost all impurity, and deposits it in the soil, where it serves as food for plants.

We are so nearly ignorant of the exact nature of the morbific ingredients in bad air, that we are obliged to be content with analyses which determine a few of the principal ingredients, and some of these in the roughest way. The term "albuminoid ammonia," for instance, stands for a great deal of ignorance of the minute composition of the organic impurities in air. In general, it may be said of most analyses of air that they chiefly inform us in regard to the degree to which dilution of the impurity with fresh air has been effected. This is practically a most valuable piece of knowledge, for whatever may be the materies morbi, the products of decay become harmless if sufficiently diluted with fresh air.

Rain.—This great purifier of the air may be made useful by the chemist as an index of the matters suspended in air. It does for him that which he does less effectually with his bottle and aspirator. As illustrating the history of the impurities of air, the following *résumé* of conclusions by R. A. Smith is here given:

1st. The rain from the sea (Western Islands) contains chiefly common salt, which crystallizes clearly.

2d. The rain contains sulphates in larger proportion to the chlorides than is found in sea-water. This is true from central Germany to the most northern Hebrides.

3d. The sulphates increase inland before large towns are reached. They seem to be a measure of the products of decomposition, the sulphuretted hydrogen from organic compounds being oxidized in the atmosphere [and forming, first SO_2, and then SO_3]. In other words, just as I believe chlorides, with proper deductions, to be a measure of the sewage, however old, in water, so I believe sulphates to be a measure of the sewage in air, unless when coal interferes too much to permit allowance to be made.

4th. The sulphates rise very high in large towns, because of the amount of sulphur in the coal used as well as of decomposition. [This statement is applicable rather to "soft," or bituminous coal, than to that commonly used in America, anthracite. The atmosphere of our cities, with few exceptions, is very little contaminated with SO_3.]

5th. As sulphuretted hydrogen and sulphide of ammonium oxidize in the atmosphere, the sulphates may be expected to increase in proportion to the amount of decomposing organic matter containing sulphur, such as albuminoid compounds, called conveniently by a name now less used—protein.

6th. When the sulphuric acid increases more rapidly than the ammonia, the rain becomes acid.

7th. When the air has so much acid that two or three grains are found in a gallon of the rain-water, or forty parts in a million, there is no hope for vegetation in a climate such as we have in the northern parts of this country (England).

8th. The acid is calculated as dry sulphuric, but, to some extent, the agent may be hydrochloric rendered free by the sulphuric acid decomposing the common salt.

9th. Sulphate of soda increases in the rain as coals are burnt; and if the salts are heated, chloride of ammonium comes off, and sulphate of soda remains.

10th. Chlorides increase with the burning of coal to a perceptible extent, although not so much as in places where salt is decomposed, whether in alkali or other works.

11th. Free acids are not found with certainty where combustion or manufactures are not the cause.

12th. The chlorides and sulphates may be found neutralized even where there are manufactures.

13th. By attending to these facts, it may be found if the plants in any place are hurt by acid, and by which acid. Other acids may probably be found as readily as the two mentioned.

14th. By attending to the amount only of the sulphates and chlorides, great injustice may be done. The acidity and the average of the district must be known.

15th. Ammoniacal salts increase in the rain as towns increase. They come partly from coal and partly from albuminoid substances or protein decomposed.

16th. The albuminoid substances may be found in the rain even by the rude experiment of burning the residue, which renders unmistakable their peculiar odor; but they may also be recognized and estimated by the method used by Wanklyn for potable water.

17th. Experiments in the direction here indicated may enable us to study and express in distinct language the character of a climate, and certainly of the influence of cities on the atmosphere.

Combustion of coal.—The products of the combustion of coal are: carbon, in the form of soot; carbonic acid, and carbonic oxide, elsewhere mentioned; sulphur, usually oxidized, and rapidly changing from SO_2 to SO_3; carbon bisulphide; ammonium sulphide or carbonate; sometimes sulphuretted hydrogen; water.

Some of these vapors are most destructive to vegetation. In the neighborhood of manufacturing towns in the north of England, on fields much exposed to the vapors, it is said that handfuls of dead grass can be pulled up in the spring smelling strongly of the vapor (Rothwell). A remarkable result is observed in wheat exposed to acid gases. The crop may be to appearance full and ripe when scarcely a trace of grain is to be found. This dies at an early stage and withers up, while the rest of the plant takes its apparently usual course. Mosses may be seen to grow in the acid-rain of towns when trees, shrubs, and grasses disappear. "Sometimes in the direction of the prevailing wind we have observed the yoke-elm and the wych-elm damaged at a distance of about 2,000 metres from a focus of acid gas." (Belgian Commission, 1854–'55.)

Another nuisance, perhaps still worse, is the effect upon buildings. The stones, bricks, and mortar, crumble; iron oxidizes, and cannot be used for roofing; bronze is rapidly blackened, and articles of brass are affected to a great depth, losing their strength.

Sewer-gas—or, more properly, sewer-air—"is a continually varying mixture of the gases which make up the atmosphere, and a relatively small proportion of certain other gases which are formed by the decomposition of the sewage, together with aqueous vapor and vapor of organic compounds; this mixture of gases and vapors carries with it a greater or less amount of minute solid particles held in suspension. As in the case of all gaseous mixtures, each of the various gases diffuses into the surrounding atmosphere independently of the others, and when exposed to water each dissolves according to its own degree of solubility. The organic vapors and solid particles diffuse much less readily, and deposit upon various solid objects." (Nichols.)

In sewers the products of decomposition vary with the nature of the material conveyed. The principal gases are carbonic acid; marsh gas, and other compounds of carbon and hydrogen; ammonia; carbonate and sulphide of ammonium; sulphuretted hydrogen; nitrogen; carbonic oxide; and organic vapors, compounds of carbon and ammonia. The proportions also vary very greatly, being influenced by the quantity of water, the temperature, the rate of flow, the amount of ventilation, the presence of accumulated solids, etc. Marsh gas, sulphuretted hydrogen, sulphide of ammonium, are especially found when access of fresh air is impeded, as in close sewers, cesspools, and privies.

Some of these gases are known as actively poisonous; they have repeatedly produced rapid death, or dangerous illness, in persons engaged in cleaning out the places where they were generated. In a well-arranged system of sewers this should not occur; in their normally perfect condition these places are not excessively offensive, nor immediately dangerous to persons entering them. Rapid discharge of their contents before putrefaction occurs, frequent floodings, and free ventilation, reduce the sensible foulness of sewers to a trifling point, and doubtless diminish the danger of "filth-disease." But no amount of cleanliness in sewers can make it safe to let their gases leak into dwelling-houses. We possess at present no chemical tests which will assure us that a given specimen of air is free from dangerous ingredients. The "materies morbi," whatever it may be, of diarrhœa, dysentery, typhoid, etc., is inferentially traced to sewer-air; and it would not be safe to suppose that such materies is absent, even in comparatively pure air of such origin. So little can be considered as known, that even sulphuretted hydrogen, a most characteristic product, is often present in so minute a quantity as to be indistinguishable by analysis.

We are not obliged to suppose that the ordinary compounds of sulphur, nitrogen, etc., constitute the specific cause of zymotic disease; for such a cause we may rather look to the organic vapors, and putrid organic solids giving rise to vapors, and perhaps to low septic forms of organic life.

"We know," says R. A. Smith, "that the minute diminution of oxygen is not the sole cause, although it may not be entirely harmless. We know, also, that this impure air contains more carbonic acid than pure air, but it has been made clear that this carbonic acid is not the cause of infection. We may give up the ammonia-salts and nitrates, because we know their action to be such as not to produce infectious diseases, fevers, or putrefaction, or even special diseases, although they may in some respect be injurious after a long time. None of the gases or vapors known to us can be imagined to be guilty from any property of theirs hitherto found. It is true that they may lie low, or be washed down, or brought down, by rain or vapor, so as to be found in the evening fogs. Some of these may be injurious to health, but none of them have the character of albumen capable of putrefaction, and they can be included neither in the Liebig nor in the Pasteur theory, while their characters known to us do not throw light on the beginnings or progress of marsh-fevers or epidemics. We may speak with some certainty as to the latter, but on the former—namely, the marsh-fevers—there is more ignorance to be acknowledged. . . . That some evil will result is, however, likely enough, from the great mixture of substances in the evening dew of a rich clime, leaving results independently of the albuminous decompositions and organisms, but the exact knowledge is not with us. Gases, vapors, albuminoid substances, plants and animals, must all produce their peculiar effect on the atmosphere."

Illuminating gas is now so much used that its manufacture and combustion must be ranked as important sources of contamination of the air.

In the manufacture it has to be purified from carbonic acid (which lowers its illuminating power), and from gaseous compounds of sulphur, which give rise, in burning, to the corrosive sulphurous and sulphuric acids. The removal of these from the gas is effected either by passing it through milk of lime, or through moistened slaked lime placed in trays. These processes are respectively called the moist and the dry; they are very effective, but give rise to noxious and offensive odors upon removal of the lime. Another process consists in passing the gas through some mixture containing sesquihydrate of iron. It is not, perhaps, so effective as the lime process, but, as it acts by fixing the sulphur, there is little nuisance produced; besides it is very economical.

Gas thus made consists (E. S. Wood) chiefly of hydrogen (40–50 per cent.), marsh gas (35–45 per cent.), carbonic oxide (4½–7½ per cent.), olefiant gas and other hydrocarbons (4–8 per cent.), and usually very small amounts of carbonic acid and air. Cannel gas has about the same composition, the proportion of the hydrogen, marsh gas, and olefiant gas being a little different. The last-named gas is the chief illuminating ingredient.

Parkes gives an analysis nearly approaching this, as follows :

"Coal gas, when fairly purified, is composed of—

Hydrogen	40 –45.58
Marsh gas (light carb. hydrogen)	35 –40
Carbonic oxide	3 – 6.6
Olefiant gas (ethylene)	3 – 4
Acetylene	2 – 3
Sulphuretted hydrogen	0.29– 1.0
Nitrogen	2 – 2.5
Carbonic acid	3 – 3.75
Sulphurous acid	0.5 – 1.0 (or, in the best cannel coal-gas, only traces).
Ammonia, or ammonium sulphide	
Carbon bisulphide	

"In some analyses the carbonic oxide has been found as high as 11 per cent., and the light carburetted hydrogen 56 ; in such cases the amount of hydrogen is small. As much as 60 grains of sulphur have been found in 100 cubic feet of gas. The Parliamentary maximum is 20 grains in 100 cubic feet, but absolute freedom from sulphuretted hydrogen is required. In badly purified gas there may be a great number of other substances in small amount."

Roscoe gives the analysis of gas from cannel and from common coal, as follows :

	Illuminating power compared to sperm candle burning 120 grs. per hour, the gas burning 5 cubic feet.	Composition in 100 Volumes.				
		Hydrogen H.	Marsh gas, CH_4	Carbonic oxide, CO.	Heavy hydro-carbons, $(CH_2)n$.	Nitrogen, oxygen, and carbonic acid.
Cannel gas........	34.4	25.82	51.20	7.85	13.06	2.07
Common coal-gas..	13.0	47.60	41.53	7.82	3.05	...

The existence of sulphur compounds in burning-gas is to be regretted as a nearly unavoidable evil; the only remedy seems to be the discharge of the products of combustion through chimneys or flues, for which a variety of devices exist. (See article on Hospitals in this work.) "The sulphurous and sulphuric acids which are produced in burning may injure delicate structures, such as books, gilding, silks, etc., that may be exposed to the air of a room in which gas is burned. Where large quantities of impure gas are burned, it causes a rapid destruction of textile fabrics, with a very acid condition of them. This was especially noticed in the large public libraries of London many years ago; the covers of many of the books in the Athenæum club-house, the College of Surgeons, and elsewhere, becoming destroyed by the sulphuric acid from the burning gas. The amount of this acid was so great that it could easily be tasted by applying the exposed portions of the books to the tongue" (Wood).

Analyses of decayed bindings of books from public libraries in Boston, made recently by Prof. Gibbs, have not demonstrated the presence of sulphur compounds. It remains to test the question by very protracted exposure of books to sulphur fumes under conditions resembling those of libraries.

The acid products of burning-gas are deleterious to house-plants, producing instant injury in healthy individuals.

Nearly all of the sulphur is converted into sulphuric acid, which is a vapor readily condensed on the walls and other objects contained in a room. Gas not infrequently contains 30 grains of sulphur per 100 cubic feet, which in burning gives rise to 90 grains of sulphuric acid; and this is the amount which would be produced by five four-foot burners, during five hours.

Other noxious effects of gas, burnt without ventilation, may be traced to the presence of great quantities of carbonic acid,—one burner producing several times as much as a man in a given time,—of watery vapor from the hydrogen and compounds of hydrogen, and to the great heat produced by the cheap light.

When gas is partly burnt (Parkes) a considerable quantity of carbonic oxide is also produced, which usually escapes into the air of the room, and constitutes a more serious impurity than the others.

That which is known as "water-gas" is produced by passing steam over incandescent carbon, which has a very powerful attraction for oxygen, abstracts it from the steam and unites with it, to form at first a mixture of hydrogen and carbonic acid; the latter afterward loses one-half its oxygen and becomes carbonic oxide. These gases burn without light, and require the addition of about ten per cent. of petroleum- or naphtha-gas. This mixture contains from thirty to forty per cent. of carbonic oxide, and would be excessively dangerous to life if it were inodorous, as in some instances it is.

Effects of Bad Air.

It remains a desideratum to ascertain, by the methods of experimental physiology, the effect of bad air *per se*, as compared with that of concomitant bad circumstances (diet, filth, etc.), in producing disease. The facts we have are statistical. In the absence of "exact" proof, our most delicate test of the unhealthiness of a condition is furnished—first, by the health returns of large masses of persons living under those conditions; and second, by returns from specially sensitive or specially exposed classes. The reader will at once recall many classes specially *exposed* to the influences of crowding and close air. Specially *sensitive* classes exist in the case of the wounded of an army, and of patients after amputation or child-bed, and also in the infant population.

One of the most obvious effects of an insufficient supply of air is the discomfort occasioned in those who are not habituated to the deprivation. This discomfort is an evidence of positive injury, and may increase till headache, prostration of strength, gastric disorder, and fainting occur. Closeness of air, not producing such marked symptoms, may cause dyspepsia and impairment of the general nutrition—symptoms which are now recognized as related to the development of phthisis.

In the British army, previous to 1836, it was stated[1] that the mortality from consumption was very considerable. In the Household Cavalry it was 81; in the Dragoons and Dragoon Guards, 77; in the West India depots, 96; but in the Foot Guards it was 141 in 10,000; the deaths from *all causes* among the Metropolitan Police being only 90. At the same time, "in the metropolitan barracks, a room, 32 feet long and 20 broad, was all the convenience then afforded for the eating, sleeping, and general living of twenty men and non-commissioned officers, some two or three of the men being in all probability married." Such a room would probably not afford to each inmate more than from 250 to 300 cubic feet of air, or from a fourth to a third of the prison allowance. Some barracks were very much worse than this.

A similar excess of phthisis occurs in the armies of most of the European states, and cannot be accounted for except by referring it to the bad air in barracks. In the English navy similar facts are pointed out, forming an illustration of the way in which excellent climatic conditions,

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[1] Journal of the Statistical Society, Vol. II., 1839, p. 250.

with nearly perfect arrangements in respect to daily life, may be vitiated by the one factor of bad air.

Two prisons[1] in Vienna are thus compared:

In that of Leopoldstadt, which was very badly ventilated, there died, in the years 1834–'47, 378 prisoners out of 4,280, or 86 per 1,000; and of these no less than 220, or 51.4 per 1,000, died from phthisis; there were no less than 42 cases of acute miliary tuberculosis.

In the well-ventilated House of Correction there were, in five years (1850–'54), 3,037 prisoners, of whom 43 died, or 14 per 1,000; and of these 24, or 7.9 per 1,000, died of phthisis. The comparative length of sentences is not given; but no correction on this ground, if needed, could account for this discrepancy.

Prison life, even under good conditions as to ventilation, often impairs the health.

Bad air in mines produces its effects upon the respiratory organs; though here the cause is complicated by the existence of dust and peculiar gases. It was stated by Simon (in the Fourth Report of the Medical Officer of the Privy Council) that English miners, as a class, were broken down by bronchitis and pneumonia, especially after the age of thirty-five; but that in the mines of Durham and Northumberland, where ventilation was good, this did not occur.

Hospital gangrene, it is believed, can be entirely avoided by treatment in the open air or under tents. Pyæmia and erysipelas are diseases of similar origin, and haunt old hospitals. (See remarks under "Ventilation" and "Hospital Construction.") The widest contrasts possible, as regards results, are furnished by the records of the old and by those of the new method of treating army patients and civil surgical cases. In the Crimean war, for instance, the hospital at Scutari at one time contained 2,500 sick and wounded, of whom two in five died; the annual mortality from disease in the British and French armies, in the same war, was 23.2 and 30 per cent. of the total strength; while in the American war the corresponding mortality was less than 6 per cent.

Stromeyer observed the remarkable effect of ventilation in arresting military granular conjunctivitis.

Camp-fever may be almost banished by cleanliness and fresh air. Among the earlier experiments in this direction, one of the most interesting is that made by Dr. Brocklesby.

In 1758, when the wounded were sent from France to the Isle of Wight, Dr. Brocklesby built an open one-story shed for a hospital, large enough for one hundred and twenty patients. He found that "remarkably fewer died, though treated with the same medicine and the same general regimen, than died anywhere else." In 1760 he constructed another shed-hospital in the same place, for forty patients, during a fever epidemic. The mortality was very slight, and he says of it: "I candidly ascribe their fortunate escape more to the benefit of a pure, keen air they

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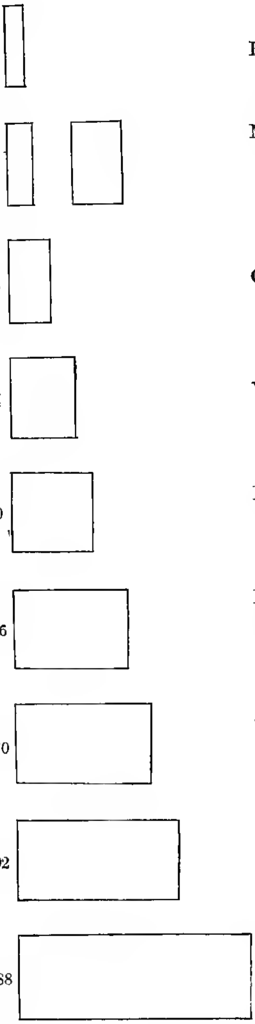
[1] Parkes' Hygiene.

breathed therein every moment than to all the medicines they took every six hours or oftener."

The following table illustrates to the eye the effects of various degrees of overcrowding in certain notorious instances. It is given by Guy, l.c.:

Effects of Overcrowding.



Cubic feet.		
20	Black Hole, Calcutta.	Of 146 persons, 23 left alive after 10 hours. Fatal fever in survivors.
30 to 60	Marlborough House, Peckham, City of London Union Workhouse.	130 fever patients sent to London Fever Hospital in one year; one-fifth of total in hospital.
52	Church Lane, St. Giles's.	Great mortality among children and adults. Fever. Cholera.
84	Village in Dorsetshire.	Fatal fever.
100	Parish House near Launceston.	Cholera.
136	Drouet's Establishment for Pauper Children, at Tooting, January, 1849.	170 deaths from cholera in three weeks.
170	Cambridge Town Bridewell, 1774.	Jail fever.
202	Printing Office.	Consumption.
288	Christchurch Workhouse, Children's Sick Ward, 1848.*	Gangrene of the mouth.

Prison allowance, 1,000 cubic feet.

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* In one ward 132 cubic feet. 288 cubic feet is the average of a number of wards.

The deprival of fresh air produces phthisis, in like manner, in some of the lower animals. Dr. Neill Arnott relates the following story about the monkeys in the Zoological Gardens of London: "A new house was built to receive the monkeys, and no expense was spared which, in the opinion of those intrusted with its management, could insure to those natives of a warm climate all attainable comfort and security. Unhappily, however, it was believed that the object would be best secured by making the new room nearly like what an English gentleman's drawing-room is. For warming it, two ordinary drawing-room grates were put in, as close to the floor as possible, and with low chimney openings, that the heated air in the room should not escape by the chimney, while the windows and other openings in the walls above were made as close as possible. Some additional warm air was admitted through openings in the floor from around hot-water pipes placed beneath it. For ventilation in cold weather, openings were made in the skirting of the room close to the floor, with the erroneous idea that the carbonic acid produced in the respiration of the animals, being heavier than the other air in the room, would separate from this and escape above. When all this was done, about sixty healthy monkeys, many of which had already borne several winters in England, were put into the room. A month afterward more than fifty of them were dead, and the few remaining ones were dying. . . . It was only necessary to open, in the winter, part of the ventilating apparatus near the ceiling, which had been prepared for the summer, and the room became at once salubrious." The cause of this mortality was consumption.

The horses in the French army formerly suffered an enormous mortality. Before 1836, the loss was from 180 to 197 per 1,000 annually. Enlargement of the stables and an increased allowance of air reduced this loss during the next ten years to 68 in 1,000.

Similar facts are stated in regard to the English cavalry horses. The losses are at present reduced, by improved stabling, to 20 in 1,000. In the Prussian cavalry, it is 15 per 1,000. In the North German army, the allowance of cubic space per horse is from 31 to 39 ctm., say 1,100–1,400 cubic feet, nearly.

About thirty years ago, a severe epidemic of influenza appeared in Boston. At the instigation of Prof. H. I. Bowditch,[1] every stable in the city was investigated, and classified as "excellent," "imperfect," or "wholly unfit," in respect to warmth, dryness, light, ventilation, and cleanliness. It was found that in the first-class fewer horses were attacked, and the disease was milder, while in the third-class every horse was attacked, and more severe and fatal cases occurred. In respect to the number attacked and the general characteristics of the disease, the three classes stood to one another as 1 : 3 : 5.

In the four years ending in 1784, of 7,550 infants born at the ill-ventilated Dublin Lying-in Hospital, 2,944 died of epidemic disease; while,

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[1] Seventh Report of Massachusetts Board of Health, 1876.

after a thorough system of ventilation had been adopted, only 279 died in the same number of years.

At the same time, scrofula (or more correctly, tuberculosis) was so common in public institutions as to be commonly considered a contagious disease. Its cause was plainly overcrowding.

The sensitiveness of the digestive organs to foul air in the hot season is well known. It is not the heat of itself that produces diarrhœa. If heat does not act as a debilitant, and thus predispose, the bowels are not deranged. Pure, very dry and hot air, in countries like Arizona and Arabia, is compatible with perfect health; but a certain comparatively moderate heat in close cities, where atmospheric moisture and general filth are present, with imperfect circulation of air among the houses, is sure to be productive of infantile bowel complaints, and is very likely to engender them in adults, though with less quickness, in proportion to the superior power of resistance.

Heat and Moisture.

The atmosphere has a very important influence upon the health and character of man in other ways than by supplying him with suitable or unsuitable chemical elements. The physical condition of the air, in respect to temperature, moisture, pressure, motion, and precipitation are factors of the highest importance. Taken collectively, they may be grouped under the title of climatic influences.

In explaining this part of the subject, care will be taken to make such statements as seem required for a thorough comprehension of the elements of climate; and afterwards an enumeration of the classes, the characteristics, and the sanatory effects of special "climates" will be attempted, with some directions regarding meteorological observations.

Sources of heat.—The chief part of the heat employed in natural processes upon the earth's surface is derived from the sun. With this must be included heat obtained from combustibles—mineral coal, wood, oils, etc.—all of which represent stored-up force, originally derived from the action of the sun's rays in promoting vegetable life. The chemical actions which produce animal heat derive their forces ultimately from the same source.

The earth itself, as is well known, possesses an internal store of heat, which at present is undergoing an extremely slow diminution by conduction through the upper strata. In descending the shafts of mines, the temperature is found to rise constantly, at the rate of about 1° F. to every 53 feet of descent. In six of the deepest mines of Northumberland and Durham the rate is 1° F. for 44 feet; in the Saxon argentiferous lead-mines it was found to be 1° in 60 feet, and the same in boring the well of Grenelle at Paris. A boring at Louisville, 2,086 feet in depth, gives an increase of 1° in 76 feet· one at Columbus, Ohio, of 2,575 feet, gives 1° in 71 feet.

The crust of the earth is, however, a very poor conductor of heat.

Owing to this fact, the internal temperature influences the surface to the extent only of $\frac{1}{30}^\circ$ or $\frac{1}{40}^\circ$ C. (Th. Langer), say $\frac{1}{17}^\circ$–$\frac{1}{22}^\circ$ F.

The atmospheric fluctuation, taken by the day, the month, or the year, produces a like fluctuation in the temperature of the upper strata; this extends to depths bearing definite relations to the length of the period observed; and there is at last a point reached where the temperature is invariable by night and day, by winter and summer. This point lies from 80 to 100 feet below the surface in temperate latitudes.

The measurement of temperature by the thermometer requires certain precautions, which are described hereafter.

Transmission of Heat.

Leaving out of consideration all theoretic views as to the absolute nature of heat, it is evident that its transmission from one body to another is effected in three distinct ways; and these three are denominated *Conduction*, *Convection*, *Radiation*.

Conduction occurs in solids; in fluids it occurs to so very slight an extent that it may practically be said not to exist, except in the case of mercury. In gases conduction occurs to a slight extent, but in variable degrees. It consists in a gradual transference or propagation of heat from particle to neighboring particle, proceeding only so far as immediate contact exists, and arrested by solution of continuity.

The metals are among the best conductors of heat. The worst conductors are bodies in a porous or pulverized state, such as straw, down, wood, sand, sawdust; this is owing to the presence of a large amount of air confined, in the meshes of the fabric or between the particles of the powder, air itself being an extremely poor conductor. Gypsum, asbestos, and glass, furnish well-known instances of solid bodies which are very slow conductors.

Convection occurs in liquids and gases. It signifies a transference of heated particles, in the form of currents, arising at the point where the gas or liquid is in contact with a heated body, and circulating through the entire mass. Such currents are familiarly known in the case of boiling water; and every one has seen them in the air around hot stoves. The portion which is heated expands, rises, and is immediately replaced by a fresh portion, so that the mass is heated by having every particle brought in actual or approximate contact with the source of heat. The heat is further equalized, and communicated to remote parts, by the process of circulation.

In the distribution of terrestrial heat, *i. e.*, of heat which has been communicated to the earth from the sun, convection plays a most important part. The atmosphere is kept in a state of constant motion, almost exclusively by this process. The ground, heated by the sun's rays, imparts heat to the air above; the air expands, rises, and its place is filled by air from some less-heated spot, which in its passage is called wind.

Upon the sea-coast, and in islands in the sea, this phenomenon occurs with regularity during the warm season. When the morning sun has acted a certain number of hours upon the surface of the land, it becomes warmer than the sea; the air above the soil rises, and fresh air pours in from the sea on all sides. This produces what is called a sea-breeze; in summer it begins in the early forenoon, is strongest an hour or two after noon, and ceases at sunset.

In the evening, the reverse takes place, the land cooling rapidly, and sending off currents called a land-breeze towards the water, which is not subject to these diurnal fluctuations of temperature.

The trade-winds are produced in a similar way. The equatorial belt of the earth's surface is heated to a high temperature by the sun; its atmosphere rises in a mass, and is replaced by cooler air from the north and south. Thus there are formed pairs of currents: *from* the north and south there come cool under-currents, along the surface of the earth; and *to* the north and south there pass warm upper-currents, at a distance of many thousands of feet above the earth's surface. In high latitudes the warmer currents descend in places to the earth, producing those south-westerly winds which are known for their mildness in many parts of the world. Thus the earth's atmosphere is furnished with a circulatory system precisely analogous to that which exists in a chamber warmed by a porcelain stove.

The importance of this arrangement, in furnishing warmth to the regions near the poles, and coolness to the equatorial zone, cannot be overestimated; it forms one of the principal chapters in the history of climates.

The trade-winds blow constantly from the north-east, in a belt between the equator and the 32d parallel of north latitude; and from the south-east in the corresponding region south of the equator. This change of direction from that of due north and south is accounted for by considering that the air, in coming near the equator, is continually passing to greater and greater circles (parallels). Each successive parallel attained by the wind is greater than the one left behind; consequently, the velocity of rotation of the surfaces passed over by the wind is constantly increasing. Before the air can acquire the increased velocity by contact with the earth, the earth has whirled away from under it some distance to the east, which gives the effect of a wind moving to the west—or (combining this with its equatorial tendency) to the south-west or north-west.

As regards the upper, or "equatorial" current, its existence is demonstrated upon the summits of many intertropical mountains, as the peak of Teneriffe, 12,180 feet high, and Mauna Kea, in the Sandwich Islands, 18,400 feet high. Its rapidity of movement gradually diminishes toward the poles, at which point the motion almost vanishes.

Other currents, producing winds of contrary direction in the temperate zones, will be described under climate.

The North-east and the South-east trades are separated by a belt of calm, averaging 6° in width, upon the equator. This belt, and the range of the trades to the north and south, varies with the seasons, being a few degrees further south in our winter than in our summer.

The ocean water undergoes a similar influence, but the currents produced are very much less regular, though their general effect is to transport warm water on the surface toward the colder parts of the earth, and cold water at a lower level in the opposite direction. The effects in mitigating the severity of winter are manifest along the western coasts of Europe, and impart to the climate of the British Isles a rare mildness and aptitude for supporting life.

Radiation is entirely different from either conduction or convection. In this process heat is conveyed through space without the intervention of any solid, liquid, or gaseous substance known to chemical science, *i. e.*, through a vacuum. Radiation takes place also through certain solids, liquids, and gases, and when this occurs they may be said to be transparent to heat (diathermanous). But in the latter case the transmission is much retarded; heat moves through a vacuum three times as rapidly as through air. It will be easy to see that the passage of radiant heat does not necessarily imply the warming of the body it passes through, although this occurs to some slight extent in many bodies, in proportion to the absorption of heat that occurs. The atmosphere, for instance, when free from moisture, permits the sun's rays to pass to the earth with but a slight loss from absorption; it does not become directly warmed to any great extent by the sun's rays. It is estimated that four-fifths of the heat-rays of a perpendicular sun pass the atmosphere without absorption, in very clear weather. (Langer.)

Conditions of radiation.—In general, rough bodies, those of a dull surface and of high density, part readily with heat by radiation, while polished and light substances radiate slowly. The surface of the earth is a very good radiator, and parts with heat rapidly when uncovered. Absorption of radiant heat is also effected most readily by a dull, rough surface. The color of a substance, which does not affect the process of radiation, is very important in absorption. Franklin observed that snow melted most rapidly when covered with black cloth, and in a successively diminishing rate under blue, green, purple, red, yellow, and white cloth.

The comparative radiating power of a large number of substances is given by Loomis; the following are extracted :

Hare skin	1316
White raw wool on grass	1222
Raw silk	1107
Long grass	1000
Grass less than an inch in height	870
Glass	864
Wood	773
Iron	642
Sawdust	610
Garden-mould	472
River sand	454
Stone	390
Brick	372
Gravel	288

Radiant heat may be *reflected*, *absorbed*, or *transmitted;* and as transmitted it may also be *refracted.* Of reflection of heat it is unnecessary to speak at length.

The conditions of *transmission* are the following:

The capacity of a given body to transmit heat varies with the source of heat. The solar heat is transmitted by glass, while the heat of a fire is almost wholly cut off. Ice acts in a similar way. Pure water arrests radiant heat almost wholly. The atmosphere lets the sun's heat pass freely to the earth; but when the heat has been absorbed by the earth a change seems to have come over it, for the vapor of the atmosphere absorbs a very large part of the radiant heat of the earth. This points to an essential difference in the quality of the heat from different sources, which is further confirmed by finding that different sources of terrestrial heat—*i. e.*, the flames of different substances—radiate heat in unequal proportions through media which, in other respects, have similar conductive powers.

The capacity of different bodies to transmit radiant heat also varies with the same source of heat, and this in a paradoxical way. Black glass transmits heat-rays with facility, while transparent glass cuts them off. Brown rock-crystal and opaque rock-salt also transmit well. The power of a body to transmit radiant heat is called diathermancy.

To illustrate this point the following statements are quoted from Melloni: "The heat of a naked flame is directed through plates of various substances, 0.102″ thick. The percentage of the total amount that passes through is: for rock-salt, 92.33; for plate-glass, 39; for sugar-candy, 8. A sheet of liquid of given thickness (0.362″) transmits as follows: turpentine, 31 per cent.; olive oil, 30; ether, 21; alcohol, 15; distilled water, 11. Of the gases, air, when perfectly dry and pure, transmits all of the heat; and so do hydrogen, nitrogen, and oxygen. Carbonic acid, however, transmits only $\frac{1}{90}$ of radiant heat, street gas $\frac{1}{970}$, and ammonia $\frac{1}{1195}$. Atmospheric moisture greatly increases the absorbent powers of air; when saturated, air has its diathermanous power diminished $\frac{1}{20}$. The presence of vapors of ether and ammonia in vapor has a similar effect, and so have the perfumes of flowers, which have a specific value in retaining the sun's heat during inflorescence, where great heat is required.

In connection with these statements, the reader will recall the fact that the refraction of a sunbeam analyzes it into three components: rays of light, red, green, and violet; rays of heat; and rays possessing chemical activity (actinism), both the latter being invisible. These three sets of rays overlap each other, but in such a way that the actinic rays are more powerful near the violet end of the light-spectrum, while the heat rays are strongest near the red end. Each of the two latter forms its own (invisible) spectrum; it is susceptible of analysis into rays of greater or less refrangibility. And it is found that heat from feeble sources is much less refrangible than that from more energetic bodies. The heat of the sun is the most refrangible, its rays covering the whole spectrum of light, and reaching far beyond the red ray; then follow in order that from the flame of a lamp, from incandescent platinum, from copper at 750°, and from water at 212° F. It would seem, therefore, that glass, while transmitting all the rays of color, transmits only that portion of the rays of heat which is most refrangible.

Heat of Composition.

It is necessary to state that temperature, or sensible heat, is a very different thing from actual heat. Two bodies of equal weight containing very different amounts of heat may give the same temperature, as tested by the thermometer. In explaining this, we have first to consider what is called latent heat, or heat of composition.

In passing from the solid to the liquid state, a large quantity of heat may be poured into a body without any appreciable rise of temperature. If ice at 32° be placed over a lamp, the heat of which can be measured, it will be found that during the act of melting, a quantity of heat is used sufficient to have raised the temperature of a corresponding quantity of water to 182° F., while at the end of the melting, the water produced is not sensibly warmer than 32°. We say, therefore, that the ice has absorbed 140° of heat. A similar absorption occurs in the melting of all solid bodies. The heat which thus enters into composition with a body, and is required to maintain it in a liquid form—heat, whose energy is diverted to the maintenance of a new molecular condition—is called heat of composition; it becomes imperceptible to ordinary tests, like the water of composition in mineral bodies.

The heat thus absorbed is termed *latent heat of liquefaction*, or *fusion;* or *heat of fluidity*. And that which is absorbed when fluids pass into a gaseous state (for the same thing occurs here) is called the *latent heat of vaporization*. Water at 212° requires the addition of 967° F. (Rodwell) to bring it into the state of vapor by boiling; water at ordinary temperatures requires much more to evaporate it without ebullition.

In all cases this heat is recovered, and appears as an agent sensible to the thermometer, when gaseous bodies are reduced to liquids, or liquids to solids.

Evaporation is due to the presence of heat; and it will aid our conceptions if we consider heat as the sole cause of evaporation. It occurs with perfect readiness *in vacuo*, and its total *amount* is very slightly affected by the presence of air. Its *rapidity* is, however, greatly modified by this and certain other circumstances. Rapid motion of the air in contact with the fluid, and a great extent of evaporating-surface, hasten the process very much; while, on the other hand, it is retarded in proportion to the pressure under which it occurs. When the atmospheric pressure is entirely removed, water boils at 70° F.; under one atmosphere (14.6 lbs. to the inch), it boils at 212°; under an additional atmosphere, at 250°; under three, at 275°; under four, at 294°.

Evaporation takes place *more readily* in a vacuum than in air, on account of the reduced pressure, because pressure of necessity tends to keep the molecules of the liquid together, and, when that pressure is removed, the molecules can more readily assume the gaseous condition (Rodwell). A liquid evaporates far more slowly in a space containing air, or gas of any kind; but the ultimate amount is the same.

The elastic force or tension of aqueous vapor increases with its temperature; the fact, familiar in the case of steam above 212°, is also true at the lower temperatures of the atmosphere we inhabit. Hence, as the temperature rises, a greater capacity to resist the atmospheric pressure is developed, and more vapor is formed from the water which happens to be at hand. That is, evaporation is increased. This is illustrated in the next table, in columns 3, 4, 5.

The addition of aqueous vapor to air lessens its specific gravity, though but slightly. As is seen in columns 2 and 3, the addition of vapor causes a considerable expansion of volume, and the specific gravity of the vapor is not sufficient (it is less than that of air) to bring the weight up to what it was in the dry state.

Air, as its temperature rises, loses greatly in weight; and this, of course, is equally true of saturated air, as seen in column 6.

As the temperature rises, the amount of vapor capable of retaining the gaseous state increases very rapidly, as seen in column 3. And correlatively, the depression of a few degrees in temperature, when very warm air is saturated, will produce a great precipitation in water. This explains the great copiousness of the rains which characterize the season of changeable weather in the tropics (rainy season, corresponding to winter).

AMOUNTS OF AQUEOUS VAPOR IN 1,000 VOLUMES OF AIR WHEN SATURATED. (TIDY.)

Degrees Fahr.	1,000 vols. of dry air become when saturated (volumes)	1,000 vols. of saturated air contain aq. vapor (volumes)	ONE CUBIC FOOT OF AIR SATURATED (Barom. 30 in.)		
			Contains aqueous vapor.		Weighs in grains.
			Cubic inches.	Grains.	
10 . . .	1002.3	1.12	1.9354	0.84	592.94
20 . . .	1003.6	2.29	3.9571	1.30	580.26
30 . . .	1005.6	5.57	9.6250	1.97	567.99
40 . . .	1008.3	8.23	14.2214	2.86	556.03
50 . . .	1012.0	11.76	20.3213	4.10	544.36
60 . . .	1017.3	17.06	29.4797	5.77	532.84
70 . . .	1024.4	23.82	41.1610	8.01	521.41
80 . . .	1034.1	32.98	56.9890	10.98	509.97
90 . . .	1047.0	43.93	75.9110	14.85	498.43
100 . . .	1063.9	60.07	103.8010	19.84	486.65

The practical consequence of the above statements is further seen in the case of water. The cooling of water is accomplished by hastening evaporation. The porous jars called "monkeys"—the alcazzarras of the Spaniards—when hung up in the wind, sweat, and are cooled by the evaporation of their sweat. The human body is cooled in the same way; hence the value of a frequent supply of water to men engaged in severe toil, at forges and foundries.

It has been already mentioned that large bodies of water do not readily grow hot when exposed to the sun. The heat of the sun's rays is expended very largely in evaporating the water. Such heat as is expended in raising the temperature of the air is useful (paradoxical as it seems) in keeping down the temperature of the air; for it serves to maintain in the vaporous state the moisture already evaporated, and permits the rise of still larger quantities with renewed cooling effects. It is popularly said that air has a capacity for absorbing the vapor of water; and this expression may be retained, though strictly incorrect. Air does not absorb the vapor, but is mingled with it, each under its own independent law.

The atmosphere is estimated to contain 50,000,000,000,000 tons of water in the form of vapor, but in a state of constant transition to rain or fog, snow or hail. The amount of precipitation annually is estimated at 188,450,000,000,000 tons; of which the chief part falls upon the earth, and furnishes the supply of rivers.

Precipitation may be produced by several causes. Warm currents in the upper air, laden with moisture, when they strike against the sides of mountains, are rapidly cooled, and take the form of clouds, and rain or snow. This process may be observed in perfectly clear days. The mountain does not "gather" the clouds; but the clouds form from the passing wind, and may be seen drifting away to leeward. It is thus that the mountains become the sources of water-supply for continents. Forests, possessing a high radiating power, readily receive deposits of moisture on the leaves; they thus increase the humidity of a country, and, by consequence, the annual rain-fall.

On some occasions a warm, moist stratum may be supposed to meet a cold stratum, and become chilled by the contact. The extent to which this occurs is doubtful.

An extremely common cause of the precipitation of moisture consists in the expansion which air and vapor undergo from rapid elevation into the upper regions of air, as is explained further on, under Specific Heat.

Another form of precipitation constitutes dew. The current explanation of this phenomenon is the following: During the day the earth receives heat from the sun, which it rapidly loses by radiation after sunset. Being chilled, it is in a position to condense upon its own surface the vapor contained in the air, which assumes the form of drops of water. Rough surfaces, like hairy leaves, form the best radiators, and are consequently liberally provided with dew. On a cloudy night dew is prevented from forming, owing to the fact that radiation is arrested by the clouds. Wind also hinders the deposition, as it prevents the formation of a layer of cool air in contact with the radiating surface.

Hoar-frost consists of a precipitation of vapor in a frozen state directly upon the surface.

This, the accepted theory of the origin of dew, is doubted by Professor Stockbridge,[1] who has obtained the following conclusions:

1. The temperature of the soil, taken during seven months (May to November), averaged at night 56.370° F., and that of the air, 49.664°. For the latter four months, average at 4 A.M.: air, 41.036° ; surface of dry, cultivated soil, 50.282°; of wet, cultivated soil, 48.895°; of land in grass, between 53° and 54°.
2. Moisture condenses on the *under side* of boards and stones lying on the ground when the upper is dry.
3. The soil in summer discharges moisture into the air, instead of absorbing from it.
4. Plants exude immense quantities of water by day and night, which, being chilled by the night-air, forms dew on their surface. Weighed with the "dew" on, they are found *lighter* than they were the evening before.

The process of forming dew is imitated by an artificial cooling in the hygrometers of Daniell and Regnault.

The former consists of a glass tube bent at right-angles at two points; the middle portion is horizontal, and the two end branches hang vertically downward, with a bulb at the extremity of each. One bulb contains a delicate thermometer, dipping into a small quantity of ether. The second bulb is covered with muslin. When an observation is to be made, the muslin is wetted with a few drops of ether; rapid evaporation from the muslin follows, and the vapor of ether within the first bulb is cooled and condensed. The pressure on the ether being thus diminished, it evaporates freely, and its temperature is thus further reduced, reaching at length a point at which a ring of dew begins to be formed outside the bulb. This is the dew-point, or point at which the air deposits moisture.[2] When coincident with the temperature of the air, it would indicate absolute saturation. This, however, is of rare occurrence. Regnault's hygrometer deposits dew on a polished silver surface, which is cooled by a current of air passing over ether.

The psychrometer, or dry and wet bulb instrument, consists of a pair of thermometers, mounted for convenience on a single piece of wood—one to measure the temperature of the air, the other the temperature produced by the free evaporation of water. Evaporation in this case is produced by covering the bulbs with a single layer of light cotton cloth, kept wet by a piece of wicking, which rests with one end on the upper part of the bulb, and dips with its other end into a vessel of water. This instrument does not mark the dew-point; its dry bulb gives the atmospheric temperature, and the wet bulb the number of degrees of cold which may

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[1] Investigations made at Massachusetts Agricultural College Experiment Station, Amherst, Mass.

[2] Or, point of demarcation between the temperatures at which water is deposited and those at which it is not deposited.

be produced by free evaporation. Its value depends on the fact that a dry atmosphere evaporates water quickly, and causes a greater depression of the thermometer than a moister air. From the reading of the two thermometers, the dew-point for each degree of atmospheric temperature may be calculated, and also the relative humidity of the air—the latter being usually expressed as the ratio (percentage) of the vapor actually present to that which the air would contain at the same temperature if saturated.

Pressure being an important factor in the rapidity of evaporation, the height of the barometer must also be taken into account in estimating the atmospheric moisture.

The following is quoted from the General Meteorological Instructions, issued by the War Department, Surgeon-General's Office, Washington, August 10, 1868:

"The most accurate indications with the wet bulb thermometer are obtained when the bulb is swung, or whirled briskly with its bulb fully exposed, in which case its temperature falls until the cooling produced by evaporation is counterbalanced by that taken up from the air. . . . For each condition of the atmosphere as to warmth and moisture, a temperature exists below which water cannot be made to fall by its own evaporation. This temperature is ascertained by swinging a wet bulb thermometer until its reading becomes stationary, that is, until it ceases to fall any lower, however rapid a motion may be communicated to it.

"A psychrometer exposed to very slow currents of air, as when placed with its bulb free on all sides, in a louvre-boarded box, gives a somewhat different reading, but still, one that can be used in the calculation of humidity, although with less accurate results."

A modification of the dry and wet bulb instrument, called the hygrodeik, contains, in addition to the two thermometers, a sort of mechanical computing-table, which enables an observer to estimate immediately the relative humidity.

Specific Heat.

Specific heat is defined as the quantity of heat required to raise the temperature of a given substance one degree Fahrenheit, as compared with that required to raise an equal weight of water by the same amount.

Different substances in the same category (solids, or fluids, or gases) require very different amounts of *heat* to produce corresponding *thermometric indications.* This is not a fact of ordinary observation, but its importance in nature is very great. To take an example: If one pound of water at 40° and one pound at 100° be mixed, the product is two pounds at 70°, because the specific heats are the same. But if one pound at 40° be added to a pound of mercury at 100°, the result will be a temperature of $41\frac{3}{4}$° in each. In this experiment water appears to have a great power of absorbing heat, or of cooling surrounding objects.

The stone and earth composing the surface of the land have a much lower specific heat, and become warm much quicker under the influence of a given insolation, than the water of the sea. The surface of the sea never becomes heated as the land does, and is not capable of imparting an excessive temperature to the air; hence the comparative coolness of summer winds from the sea.

Liebenberg (quoted in Gohren) gives the following as specific heat of soils (that of water being = 1.0), for equal volumes of dry soil:

Coarse tertiary sand	0.464
Diluvial marl	0.349
Loess-loam	0.321
Granite soil	0.437
Tertiary clay	0.192

On an average, the specific heat of the land may be taken as = 0.35.

If the converse experiment be tried, it will be found that a pound of water at 100°, added to the same weight of mercury at 40°, will lose very little of its heat, and the combined heat will stand at 98¼° F. The water having in this case already absorbed a great quantity of heat, is in a position to spare enough to raise the mercury to 98° without itself losing more than 1¾°. So the ocean, in winter, spares a great deal of heat to the cold wind without becoming much chilled; and winds off the water are apt to be warmer than land breezes at that season.

The ocean may thus be regarded as a vast reservoir of heat, for equalizing the local temperature and that of the globe. Although water warmed by the sun remains at the surface, nevertheless the total effect of one day's warming is so little perceptible that the diurnal variation of temperature is only two or three degrees in the torrid zone, and four or five in the temperate zones. There are very few climates, and those strictly oceanic, where the atmosphere is limited to such narrow ranges of variation. The entire range of temperature (Loomis) for the middle of the Atlantic during the year, near the equator, is about 10°; near 30° N. lat. it is 15°; near 40° it is 20°, and near 50° it is 24°, which is scarcely one half the annual range of temperature of the most equable climates in the same latitude on land.

The following tables are taken from Regnault:

SPECIFIC HEAT OF EQUAL WEIGHTS BETWEEN 32° AND 212°.

Water	1.	Silver	0.05701
Carbon	0.24150	Tin	0.05623
Glass	0.19768	Mercury	0.03332
Iron	0.11379	Platinum	0.03243
Zinc	0.09555	Gold	0.03244
Copper	0.09515	Lead	0.03140
Brass	0.09391		

SPECIFIC HEAT OF LIQUIDS.

Water	1.00000	Bisulphide of carbon	0.2303
Oil of turpentine	0.42593	Bromine	0.1060
Alcohol	0.615	Chloroform	0.2293
Ether	0.5113		

SPECIFIC HEAT OF GASES.

Gases, equal weights.	Water the Standard.
Water	1.0000
Watery vapor	0.4570
Air	0.2377
Oxygen	0.2182
Nitrogen	0.2440
Hydrogen	3.4046
Protoxide of nitrogen	0.2238
Heavy carb. hydrogen	0.3694
Oxide of carbon	0.2479
Carbonic acid	0.3308

The specific heat of bodies is inversely proportioned to the pressure under which they are placed. A solid like copper, compressed by force of blows, not only becomes heated (which is in part due to the transference of the momentum of the hammer with change into heat), but its specific heat is permanently lessened, until it is brought back to its former density by annealing. Gases from which the pressure is removed become sensibly colder; the heat contained is not lost, but is withdrawn from observation. A gas under slight pressure, therefore, resembles water in having a high specific heat; while under a strong pressure it resembles mercury in having a low specific heat. Accordingly, air at elevated points, under lessened pressure, has increased power to abstract heat from bodies in contact with it. When brought in contact with mercury in a thermometer, this rarefied air extracts more heat from it; the thermometer "falls," and the fall is an indication of the power of rarefied air to extract more heat than condensed air from all neighboring bodies—which is what is meant by temperature. This fall of the thermometer occurs at about the rate of 1° F. for every 300 feet of elevation.[1] Hence, the coolness of table-lands and mountain peaks; hence, the great cold which aëronauts have to suffer.

The formation of clouds by condensation of vapor may evidently be

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[1] In pure air, expansion alone would lower the temperature at the rate of 1° C. for every 100 metres. But the condensation of vapor occurring at these elevations sets free so much heat as to reduce this to the rate of 0.5° or 0.6° C., say 1° F. for every 328 feet. (Gohren.)

caused by simply raising the vapor to a sufficient height above the earth; and this rise is constantly occurring under the influence of the superior levity of the vapor, warmed by the sun's rays. Hence, in tropical regions, where the sun is constantly at work upon large masses of water, a constant transfer of heat takes place from the surface of the sea to the higher regions of the air. The heat ascends and does not redescend; it is carried off in vapor, and is not returned in the rain. It results from this fact, that in some tropical regions of the earth, where water abounds, the temperature of the air never rises so high by many degrees as it does in certain comparatively northern countries where the air is dry. At Singapore (lat. 1° 17′ N.) the highest range of the thermometer is 95° F.

Climatology.

The remarks contained in the few preceding pages have related to certain points in *meteorology*—that is, to the general laws of atmospheric phenomena. As applied to the special circumstances of given districts, countries, or seas, these laws constitute *climatology*.

In describing the climate of any place, the leading facts to be stated are those regarding *temperature;* then, *moisture;* and afterward, *wind, rain, barometric pressure.* These elements, however, are so closely related that it will be well to treat of them as forming one connected system. The first point to be known in regard to a climate will be assumed to be its *temperature.* The others will be spoken of as subordinates, either as contributing to raise or depress, to steady or to vary the temperature of a place, or else as dependent upon the temperature.

The *thermometer* chiefly used in this country is that of Fahrenheit, which has a scale of 180° between the freezing-point and the boiling-point of water (32° and 212°). The centigrade thermometer divides the same scale into 100°; it numbers the freezing-point 0°, the boiling-point 100°. To reduce degrees of the latter (also called the Celsius thermometer) to degrees of Fahrenheit, multiply by 9 and divide by 5, and add 32 to the quotient. If a minus quantity in degrees centigrade is to be expressed in Fahrenheit's scale, subtract the above quotient from 32°.

The Réaumur scale is reduced to Fahrenheit's by multiplying by 9 and dividing by 4, and adding the quotient to, or subtracting it from, 32°, according as the quantity is positive or negative.

In recording temperatures, it is of use to have three instruments: one ordinary upright thermometer, and two of the self-registering sort—one for maxima, and one for minima.

The *sun-maximum*, or "solar radiation," thermometer measures the heat which the direct rays of the sun are capable of imparting to solids. The bulb is blackened; the instrument is mercurial, and is contained in a glass-case which shelters it from currents of air. A constriction in the neck of the bulb holds the column of mercury at the maximum point.

The following directions will be found of practical use to observers:

"The thermometer[1] should be placed in the open air, but under a roof of some kind, and should be well sheltered toward the south. It should be protected not only from the direct rays of the sun, but from the influences of all surfaces which strongly reflect the sun's heat, and of all large bodies, such as thick walls, large rocks, etc., which become great reservoirs of heat during the day and of cold during the night.

"What it is desirable to ascertain by thermometer is the general temperature of the air at some given distance above the ground, and to do this properly the instrument must be freely exposed to the external atmosphere, but protected from local radiations.

"Besides the circumstances alluded to above as affecting the thermometer, the height of the instrument above the ground must be taken into account, and also the character of the ground immediately beneath it—both matters of some importance. The height which it is deemed best to fix upon is that of four feet from the ground to the thermometer bulb, and the surface under the thermometer should be of short grass, sufficiently exposed to the sun and wind to keep it from habitual dampness.

"A thermometer-box, in which most of the instruments used and recorded at the station are suspended, is generally used for the best-conducted meteorological observations, and one should be made and set up at every post where there are means of constructing it. This box, which should be at least two feet square, is preferably made of louvre-boards or overlapping slats; but ordinary boards pierced with numerous half-inch holes may be used instead. It should be open at the bottom, and have a roof which will shed rain. One of the sides should be hinged for convenience of access to the interior, or the box may be left permanently open towards the north, a piece of board or of canvas being used to protect it against driving winds from that quarter. This box is to be well secured on posts, at the proper height from the ground. It should be sheltered from the sun between sunrise and 7 A.M., and between 11 A.M. and 3 P.M., special screens being erected for the purpose, if necessary. These screens, as well as the box itself, should be whitewashed or painted white.

"Thermometers now made for the medical department are so mounted as to give the freest exposure to the air and the least opportunity for the retention of moisture about the bulb.

"As a general thing, thermometers which have been kept for some time will read higher than a new standard, and if the thermometer has been originally an inferior one the amount of its error will vary at different temperatures."

The point of 32° F. should be verified each year, at a time when there is a slight thaw going on in the shade. The thermometer should be plunged for half an hour, nearly to the 32° mark, in a vessel full of wet

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[1] General Meteorological Instructions, War Department, Surgeon-General's Office, Washington, August 10, 1868.

snow or ice that is beginning to melt, with only enough water to fill up the interstices.

A large number of observations, systematically made, form a basis for calculating *means*, *variations*, and *ranges* of temperature, and their laws.

The mean height for any given place is ascertained from hourly observations, taken day and night for a series of years. The mean may be calculated either for the whole year or for the separate months, or for each day in the year. The mean temperature for the whole year is of importance, but by itself is far from conveying the information desired by a person about to reside in a place; such a person wishes to know the temperature for the *months* he intends to spend there.

The yearly mean for a given place is the leading fact in respect to its climate *as a whole*, and this mean is very nearly the same from year to year. A variation of four or five degrees is sufficient to constitute a very cold or a very hot year; and a corresponding difference in the annual mean of two places represents a difference in climate corresponding to that between New York and Richmond, whose means are respectively 51.7° F. and 56.2° F. In most places the difference between extremely cold and extremely hot years is much less than 10°. It has rarely been greater at any place.

A useful chart of the temperature of a given place may be made containing three curves: first, that of the mean of each month; second, that of the highest observation in each month; and, third, that of lowest observations. The first shows the general amount of heat and its rate of increase and decrease (monthly variation) during the seasons; the second and third, taken together, show the monthly oscillation—a fact of extreme importance to all delicate persons.

The curve of *monthly* variation represents a complete natural cycle of time. Another natural cycle is that of the day; and the *hourly* variation in temperature constitutes another most important element in climate. This factor is extremely regular for a given place. It is usual to find that the curve touches its lowest point about an hour before sunrise, and its highest about two hours after noon. This, however, is not the same at different seasons and for different places.

Where the annual range is great, the monthly and daily ranges are also usually great.

It will be useful to note the reason why the time of greatest heat does not fall at noon, when the earth is receiving the greatest amount of heat from the sun. The fact is a universal one, and serves to illustrate the way in which the atmosphere receives its heat indirectly from the upper layers of the earth, and not to any great extent from the direct action of the rays of the sun. These upper layers of the soil require time to be warmed, and they continue for some hours after noon to add their stored-up heat to that which the sun pours upon them. In a precisely analogous way the yearly cycle of heat depends upon the effect which is produced on the atmosphere by the *accumulated* heat of the earth's surface. The accumulation is not greatest on the day when the sun is highest, but goes on increasing for four or more weeks, making the warmest weeks fall in the months of July or August. In our climate, July is the hottest month.

The coldest hour is several hours past midnight, and the coldest week is in January usually, because the process of cooling continues some time after the shortest day is past.

The mean temperature of a day is obtained in several ways: (*a*) from the average of *hourly* observations for the day; (*b*) from the average of the two *extremes*, obtained by self-registering instruments, which differs little from the preceding; (*c*) by selecting some hour in the day which experience has shown to possess a temperature equal to the average of the twenty-four hours; (*d*) from the average of two hours of the same name (*e. g.*, 7 A.M. and 7 P.M.); and, finally (with greater certainty than by any, except the first method), (*e*) from the *average of three daily observations.* The mean obtained in this way has to be submitted to a correction, ascertained by experience, and differing with the season and the location. The hours recommended by the Smithsonian Institution are 7 A.M., 2 P.M., and 9 P.M.

A self-registering photographic tracing of the thermometer may be taken, representing every moment of the day.

It has been already observed that the mean temperature is not the fact which most concerns an invalid. It is not absolute cold or heat, so much as fluctuation, that tries the endurance of delicate constitutions and annoys even robust persons. We classify climates by their ranges. A great range for the year or for the day is characteristic of climates deprived of the equalizing influence of water—that is, of *continental* climates. A small range, on the other hand, is found in *marine* climates.

The temperature of a place is affected by many circumstances. The three most important are the latitude, the height above the sea, and the presence of water or of atmospheric vapor. Other conditions of great importance are the neighborhood of forests, the conformation of the surface, the composition of the soil, the wind, sunshine, and so forth.

Latitude.—This is on the whole the most important factor. At the equator, the distribution of heat among the seasons is most equal, while beyond the tropics the year is characterized by six months of increase, with a very gradual and retarded warming of the surface of the earth, and six months of the reverse. "Near the equator, the entire annual variation of temperature is very small, and the greatest cold may occur in any month from November to March, or even from July to September. At some places near the equator there are two annual maxima of temperature and two minima. In the extreme south of the United States the greatest cold usually occurs in December; near the parallel of 40° it occurs about the middle of January; in the northern part of the United States, about the 1st of February; at Toronto it occurs as late as the middle of February; and in latitude 78° the greatest cold occurs in March. Throughout most of the United States the maximum temperature occurs about the middle of July; but at some places north of the

United States the maximum does not occur until the 10th of August." (Loomis.)

The sun in winter (*i. e.*, in what is winter to the northern hemisphere) is in perihelion, and gives a greater amount of heat to the earth, which is to the amount in summer as 1.034 to 0.967. For us, however, this is more than made up by the great advantage of a more vertical radiation.

The distance of a place from the equator is, on the whole, the most potent factor in determining the climate of a place. It is modified very much, however, by the *altitude*, or elevation, of the site above the sea-level. The lower strata of air, especially in summer, are much warmer than the upper. At a height of about six miles it may be assumed that the air is no longer affected by the radiation from the earth (Langer), and is alike summer and winter. Glaisher found that the temperature, measured from a balloon, fell 1° F. for every 162 feet in a clear day, and for every 223 feet in a cloudy day, under 1,000 feet. At 10,000 feet elevation, the depressions were 1° for 417 and 455 feet; at 20,000 feet, 1° for nearly 1,000 feet.

The same lowering of temperature occurs on mountains and plateaux. It does not follow exactly the same rules as in the free air, for the temperature near the surface is greatly affected by the ascending currents and the aërial moisture.

An actual yearly mean for an elevated place may be reduced to what would be its mean if at the level of the sea by subtracting a certain number of degrees Fahrenheit, to be ascertained by dividing the altitude (in feet) by 300. It is this reduced or theoretical mean temperature which is used in drawing isothermal lines.

A correct representation of the heat of a place is not given by stating merely its latitude. The annual mean of a large number of places being given, and those of an identical mean being selected, a line drawn through such a selected series will form an irregular curve, which, in some cases, may sweep through twenty or more degrees of latitude. Such a curve is called an isothermal line. To illustrate this: the isothermal of 50° passes through Puget's Sound, Burlington (Iowa), Pittsburg, New Haven, Dublin, Brussels, Vienna, near the northern shore of the Caspian Sea, and a little north of Pekin—thus passing through a range of twelve degrees of latitude.

Isothermal lines have been made to represent, not only the yearly temperature, but that for each month of the year.

Water.—The presence of a large body of water equalizes temperatures in a way above explained. The mildness of sea-side climates, *i. e.*, their equability, is well known. Travellers in the forests, in cool weather, seek the neighborhood of a lake for their night bivouac. The effect may be seen, for instance, in the climate of Monach, one of the Hebrides, with a full exposure to the sea winds, where the mean for January is 43.4° F., and for July 55° F. In Moscow, on the contrary, which presents a typical continental climate, the means for these months are − 10.9° C. and 19.2° C. (= 12.4° and 66.6° F.). In the one case a difference of 11.6° F., in the other of 54.2°, between the means of the coldest and the hottest months. The difference is equally palpable when the absolute range is taken—that is, the difference between the extremes at any time observed; in Moscow it equals 141° F. (between — 47° and + 94°); in Yakutsk, Siberia, 162° F. These two are typical illustrations of a continental climate.

Owing to the slowness with which the sea receives heat, the maximum temperature of sea-air is not attained till a month or two later than the air of the land. This also has its influence on the autumnal climates of sea-side places.

The effect of ocean currents upon climate is best seen in the west of Europe. Shetland enjoys a winter temperature of 39° F.; it would be 3°, if its geographical latitude alone determined its warmth: and London has a winter of 38°, which would be 17°, were it not for the heat brought from the Gulf of Mexico by that current which renders Norway habitable. Instead of estimating the climate of central and northern Europe by its latitude, we may reckon that it grows cold from west to east. The effect of the Gulf Stream upon the climate is perceptible as far as central Germany. On the west coast of North America a similar current affects in like manner the climate of Alaska and British Columbia.

A cold (polar) current, running next our own Atlantic coast, prevents us from deriving benefit from the heat of the Gulf Stream. To this add the prevalence of north-west winds in our cold season.

Another function of moisture, in the form of vapor, is the prevention of the escape of heat by radiation. It is the absence of this "blanket" that makes inland climates so cold in winter. Deserts, or tracts where little rain falls, are among the hottest parts of the earth's surface by day, but are sometimes very cold by night, owing to the excess of radiation; when situated in the tropics, they give rise to the saying that the night is the tropical winter.

The amount of rain falling at a given place depends upon several circumstances.

The excessive rainfall in certain parts of the tropics has been mentioned and explained. In some places a shower is expected every day.

The wind is the bearer of rain—or rather of vapor, which may be condensed under favoring circumstances. Its influence in the production of rain depends on several circumstances:

1. The width of the surface of water it has traversed, and the distance it has had to pass over land before reaching the place in question.

2. The relative temperature of the place the wind comes from and of the place it goes to. An equatorial current, warm and vapor-laden, deposits rain as it passes to the north and east. A polar current is cold, and therefore dry; its effect on the lands lying to the south is drying. The latter case is exemplified by the current from the steppes of Russia and Siberia, which furnishes a prevailing wind in winter over a large part of the Eastern Continent. Another instance is the north and north-west wind of our own continent, which originates in the vast northern plains,

and, coming to warmer latitudes, appears as a dry wind. Again, the heat of the sandy wastes of the Sahara is so excessive that the moist winds coming from the Mediterranean do not part with any water by condensation.

3. Moist winds deposit rain upon mountains, especially if they lie across the line of direction of the prevailing winds; and in many cases the air is so exhausted of moisture by the process, that the country lying beyond is almost rainless. The winds from the Atlantic coast are thus exhausted in the mountains which lie to the south of the Sahara; those from the Mediterranean, in parts, by the mountains on the northern coast.

The vast tracts of land lying east of the Rocky Mountains labor under a similar disadvantage, which is mitigated by their elevation and consequent coolness, and by their comparatively northern latitude.

Forests are generally credited with the power of increasing the moisture of a neighboring country. It is evident to a superficial observation that the moisture within their own precincts is increased. This fact, by itself, though interesting, does not wholly solve our doubts; certain things appear to be settled, however. The climate of a forest resembles that of an island. The presence of much moisture in the air prevents the rapid loss of heat by night, and enables a large amount to become latent by day. Hence the air is cooler by day, both in summer and winter; and by night it is warmer. The yearly maximum is 5.2° C. (= 9.4° F.) lower than in the neighboring open air (Ebermayer), and the minimum is higher; but, on the whole, the forest air is decidedly cooler than that of the plain. It seems to be the function of the woods to store up moisture. They collect it from warm moist winds, which would be less likely to give it up to the open fields, and they impart it to dry winds, whether cold or warm. This is more certain in regard to mountain forests than in regard to those on low land.

It may be added that, by protecting the snow from sudden melting and the soil from the devastation of torrents, or avalanches, trees play a most important part in maintaining a country in a habitable state.

The following statement of the average annual rainfall in several places is from Hann's tables:

PLACE.	Paris inches.	Millimetres.
Suez	1.0	28
Fort Yuma, in the Colorado Valley	2.7	75
Astrachan	4.6	124
Madrid	15.0	407
Coimbra, west coast of Spain	111.2	3,010
New York	44.4	1,201
London	18.1	490
Singapore	84.2	2,280
Sierra Leone	118.4	3,195
Cayenne	121.9	3,301
Cerra Punjee	524.5	14,198

The annual amount of rain-fall is greatest at the equator, and diminishes with some regularity toward the poles. Roughly stated, it equals, in inches—

At latitude.	Annual fall in inches.	At latitude.	Annual fall in inches.
0°	100	50°	30
20°	80	60°	20
30°	60	70°	10
40°	40	80°	5

The distribution of the rain-fall through the year differs greatly in different latitudes. At the equator there is a belt of a few degrees where a heavy shower with thunder occurs every day between noon and two o'clock. Next comes a tropical zone, with periodical rains occurring when the sun is overhead, *i. e.*, in the summer. Then a sub-tropical dry zone, extending from about 24° to 28°, which coincides with the greatest part of the deserts on the earth's surface. Beyond lies the temperate zone, divided into three belts: the warm, 28°–35°, with semi-periodical winter rains, and little in summer; the middle, 35°–45°, with equinoctial rains; and the cooler, 45°–65°, with perennial rains, but with a maximum in summer. The polar zone has a dry winter, with clear sky, but in summer a frequent fall of light rain. None of these zones strictly corresponds to the above parallels, any more than the isothermal zones do to theirs.

It should be borne in mind that the amount of rain-fall is very far from being an index of the moisture of the atmosphere. In fact, these two are often found in inverse ratio to each other. A showery climate is a disadvantage when it keeps people in the house.

A full description of the method of taking observations of rain- and snow-fall is given in the Smithsonian Miscellaneous Collections (148). The following brief note is from instructions issued by the War Department:

"The rain-gauge now issued by the Department is a brass cylinder, seven and a half inches high, with a diameter at its mouth of one and ninety-seven hundredths (1.97) of an inch; this diameter being fixed upon for the reason that one inch of rain falling through such an aperture will measure exactly fifty cubic centimetres (50 c.c.).

"The most desirable place for a rain-gauge, other things being equal, is at the surface of the ground; but, since it is not easy to protect an instrument in that situation, the gauge will be placed on the top of a post eight feet high, a countersunk hole of three inches in depth being made to receive it."

The composition of the soil affects the temperature greatly. While water equalizes the temperature, dry sand produces great extremes. Owing to the very poor conducting power of this substance, it retains a great deal of heat in its uppermost layer, giving a very high temperature to the air which passes over it by day. At night the radiation from this shallow surface is so great that frost is not an uncommon occurrence in dry, tropical countries where trees are absent. Loam and clay soils, retaining moisture, are not so hot at the surface, nor so cold by night, as sand is. In parts of the Sahara and the deserts of Arabia a mean summer-heat of 95° has been observed with a surface-temperature of 200° F., or 125° in the shade. Similar elevation of surface-heat is characteristic of the climate of India.

Conformation of surface.—The general rule of diminished temperature with increased elevation is subject to a special exception in the case of low land surrounded by hills. The early frosts of autumn attack such spots first, unless they are protected by the presence of a sheet of water.

The air at higher levels on the hills or mountains, becoming chilled at evening, or under various other circumstances, rushes down the sides into the valleys, producing that freezing blast which the traveller often encounters at the entrance of a pass. A lake surrounded by hills is notoriously squally. In choosing the site of a house, therefore, low ground surrounded by hills is objectionable for other reasons than that of excessive moisture. In Tyrol, Carinthia, and upper Austria, the peasants have discovered that a house is warmer if built upon the low foot-hills than if placed in the bed of a valley.

The wind—its origin, its relations to barometric pressure and moisture, and other points—need not be further dwelt upon here. For a description of the anemometer, the reader is referred to the publications of the Smithsonian Institution. The direction, force, and variations of the wind for given periods form extremely important elements in the climate of a place.

VELOCITY OF WIND.

Velocity.	Pressure in lbs. per square foot.	Descriptive names used by British Admiralty.
0=calm.		
1=less than five miles an hour.	.125	Light air.
2=between five and ten.	.125 to .50	Light breeze.
3= “ ten and fifteen.	.5 “ 1.12	
4= “ fifteen and twenty.	1.12 “ 2.00	Gentle breeze.
5= “ twenty and thirty.	2.00 “ 4.50	Moderate breeze.
6= “ thirty and forty.	4.50 “ 8.00	Fresh breeze to stormy breeze.
7= “ forty and fifty.	8.00 “ 12.50	Moderate gale.
8= “ fifty and sixty.	12.50 “ 18.00	Fresh gale.
9= “ sixty and seventy.	18.00 “ 24.50	Strong gale to whole gale.
10=above seventy.		Storm to hurricane.

DESIGNATIONS OF WIND ACCORDING TO ITS VELOCITY (PÉCLET).[1]

Metres per second.	
0.5	wind hardly felt.
1.	sensible.
2.	moderate.
5.5	quite strong.
10.	high.
20.	very high.
22.5	storm.
27.	severe storm.
36.	hurricane.
45.	hurricane which uproots trees and overthrows houses.

The regularity of the winds in the tropics has been noticed. In the temperate zones the upper current (equatorial moist wind) comes much nearer the earth, and often descends so as to touch its surface. This produces a rapid change of weather, with rain; and the frequency of these changes is characteristic of temperate zones in most months of the year.

Barometric pressure.—This is chiefly dependent on the weight of the atmospheric air; but the tension of the watery vapor in the air certainly affects the barometric pressure also. The pressure, lightened where the air of a place is expanded by heat and increased during cold, forms the principal cause of the production of wind. Foci of low pressure are produced over continental plains, like those of Asia and North America, in summer; of high pressure, in the same places, during winter. To these foci the air converges in summer, and from them it diverges in winter.

The observations of the barometer are classified under the following heads, which correspond to those belonging to thermometry:

Mean height for *day*, for *month*, for *year*, and that for a *place*, deduced from the average of a series of years.

Hourly variation, or diurnal oscillation,[2] derived from observations protracted for years. There are two fluctuations daily in each direction —giving maxima in the tropics, at about 9 A.M and 10 P.M., and minima at 4 A.M. and 3 or 4 P.M., or nearly so.

Monthly oscillation is the difference between the extremes observed during the month. It represents accidental changes of weather. A mean monthly oscillation is deduced from years of observation of a given month; if great, the climate is a bad or hard one, subject to great fluctuations of weather.

The yearly oscillation depends less on latitude than on the presence or absence of water. In continental climates the maximum and minimum are in winter and summer. In the sea climates of western Europe there are two maxima: at the beginning of the autumn and in winter; and two minima: in April and November.

In Pekin there is a steady rise from January to July, with a differ-

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[1] Vol. I., p. 237.

[2] Oscillation = extreme range.

ence of $\frac{3}{4}$ of an inch, and a steady fall from July to January. In London, Paris, Boston, the difference between any two monthly means does not exceed $\frac{1}{10}$ of an inch. The extremes of fluctuation, however, are much greater—in London, 3 inches, for example. In summer, maxima of pressure occur over oceans, as minima occur over continents.

Isobarometric lines are lines connecting places with the same mean annual height of barometer. The height at the sea-level is less at the equator (29.974) than on either side at 30° north and south latitude, and lessens again toward the poles, especially toward the south, from 63° to 74° south latitude, where the depression is upward of an inch. (Parkes.)

Of all the elements which enter into the composition of a climate, there is none more inimical to man's health than great variability. Robust individuals may not suffer, but the weak are injured. If we may make inferences from facts of common observation and the testimony of travellers, the health of man may be maintained unimpaired at a temperature (in-doors) of 40° or 45° F., at upward of 80° F., and at all points between.[1] Not only do native races flourish in such extreme climates, but Europeans are found to enjoy nearly if not quite as good health as at home—under proper regulations.

This point, the compatibility of the most various climates with perfect health, is of the first importance, and may be here illustrated.

One of the finest climates in the world is found in the Arabian deserts. The traveller inhales a very dry and pure air, and is exposed to abundance of light. The effect is a stimulant one, analogous to that experienced on high mountain plateaus. Many of our own countrymen are perfectly acquainted with the invigorating action on the nervous system of some of our Rocky Mountain regions and parts of California. Those who insist on the necessity of moisture for health should read descriptions, such as this by Palgrave:[2]

"In any other climate such an establishment (*i. e.*, a slaughter-house) would be an intolerable nuisance if thus placed within the city limits, and right in the centre of gardens and habitations. But here the dryness of the atmosphere is such that no ill consequence follows; putrefaction being effectually anticipated by the parching influence of the air, which renders a carcass of three or four days' standing as inoffensive to the nose as a leather drum; and one may pass leisurely by a recently deceased camel on the road-side, and almost take it for a specimen prepared with arsenic and spirits for an anatomical museum."

The variation between the temperatures of day and night, which characterizes these regions, is not necessarily a hurtful element, as it can be

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[1] The winter temperature of Cumberland House is — 2° F.; the summer temperature of Galveston is 85°. As regards arctic temperature, Dr. Kane considered it desirable, for the health of his men, to keep his cabin above 50°.

[2] Personal Narrative of a Year's Journey through Central and Eastern Arabia, 1871.

foreseen and provided against; whereas no foresight can guard a person in the Northern United States against the changes which give us for one day, or a succession of days, the climate of Richmond, and then, at an hour's warning, the climate of Newfoundland for an indefinite period. A moderate amount of daily variation, indeed, appears to be consistent with great excellence in a climate, such as that of Florida, for example; the stimulating action of a moderate change from warm to cold is probably desirable for most cases, except in persons of very feeble powers of resistance.

A moist and warm climate is felt as very depressing after a stay in a desert-air. Nevertheless, the chief danger to life, in such a climate, does not arise from this depression, but from malaria, and, when the latter is avoided, the inhabitants may be found to be very healthy.

A very moist and hot climate is found in the tropics, within the belt of daily rains, and, in spite of its direct contrast in almost every respect to some of our "finest climates" (*e. g.*, that of Minnesota in winter), it seems to deserve the reputation of great salubrity.

"In this favored zone [from 12° north to 12° south latitude] the heat is never oppressive, as it so often becomes on the borders of the tropics; and the large absolute amount of moisture always present in the air is almost as congenial to the health of man as it is favorable to the growth and development of vegetation. Where the inhabitants adapt their mode of life to the peculiarities of the climate, as is the case with the Dutch in the Malay Archipelago, they enjoy as robust health as in Europe, both in the case of persons born in Europe and of those who for generations have lived under a vertical sun. Again, the lowering of the temperature at night is so regular, and yet so strictly limited in amount, that, although never cold enough to be unpleasant, the nights are never so oppressively hot as to prevent sleep."[1] This climate is marked by a humidity which ranges in January from 77 to 96 per cent. of saturation; in September, the driest month, from 62 to 92.

"The effect of a tropical climate is, so to speak, relative. The temperature and the humidity of the air are highly favorable to decompositions of all kinds; the effluvia from an impure soil, and the putrescent changes going on in it, are greatly aggravated by heat. The effects of the sanitary evils which, in a cold climate like Canada, are partly neutralized by the cold, are developed in the West Indies or in tropical India to the greatest degree. In this way a tropical climate is evidently most powerful, and it renders all sanitary precautions tenfold more necessary than in the temperate zone. But all this is not the effect of climate, but of something added to climate. Take away these sanitary defects, and avoid malarious soils, or drain them, and let the mode of living be a proper one, and the European soldier does not die faster in the tropics than at home."[2]

Such are the general conclusions which we are warranted in presenting in regard to hot climates. Whether the heats of India will prevent the Europeans—and particularly the English—from becoming a permanent

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[1] A. R. Wallace: Tropical Nature, 1878.

[2] Parkes' Hygiene, p. 430.

element of the population, as they have become in Louisiana,[1] is a question which is not yet solved, though some facts seem to negative it.

The effect of climatic heat upon a new-comer is to raise the body-temperature slightly. The respirations are lessened (Rattray), being on the average 18.43 per cent. less than they were in temperate climates. The skin secretes much more, the kidneys much less than before. The digestive powers are somewhat lessened, and many experience lassitude. The power of performing work, in the case of men who have become somewhat accustomed to the new conditions, is underrated, and idleness has done more harm than fatigue to the British soldier in India.

Even in this most trying climate, however, the effects of sudden changes are very manifest. It is commonly said that the heat produces disease of the liver. It would be more correct to say that this, with other frequent affections of the digestive tract, are due to high-living and to exposure to the chilling effects of wind, voluntarily encountered for the purpose of cooling the body.

The effects of extreme cold upon the system are not necessarily harmful to the healthy majority, however destructive of feeble life they may be.

The effects of arctic cold are complicated with those of the absence of sunlight during a great part of the year. No circumstance exercises so depressing an influence, first upon the mind, and then upon all the active powers of the body and the general vigor, as this absence of sunlight; and it will be found that almost all climates regarded as specially beneficial to invalids are marked by an abundance of solar light. The mental depression of the arctic voyager is felt in a less degree by the Italian in London, or by the stranger in a foggy season at Newport. In some instances of excessive nervous irritability, this depressing influence is desirable, especially when it is conjoined with the insular mildness of a climate like that of England. But, on the whole, deprivation of sunlight is a good reason for condemning a climate. The sea-side climates, in temperate latitudes, in early summer, before the fogs have set in, are very stimulating; beyond a certain degree of heat they become too enervating for many; their *stimulant* action has a certain incomplete analogy with that of open plateaux, and their sedative action (August) approaches that of the tropics. But abundant sunlight is on the whole a characteristic of the open sea-coast.

It is now admitted that the most general test of the value of a climate consists in its suitability to be lived in: or, if this seem like tautology, the best climate is that in which a delicate person can be out of doors with comfort and safety for the greatest number of hours and days in the month. This requisition can only be fulfilled, in most cases, by the combination of *clear sky* (sunlight), *warmth* (not of the rays of the sun, but of the lower level of atmosphere), and *equability* (or freedom from violent change of temperature and chilling wind).

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[1] The case of the Southern United States is, however, quite different from that of the parched plains of India.

The equability of insular tropical climates, however, does not supply a certain desirable element—that of stimulus. For this element we must seek a mountain climate, or that of a plateau. Yet even here the rule holds good, that exposure to the atmosphere and all its influences must be sought. Immunity from phthisis is said to exist at high altitudes in various countries, and a curative influence must certainly be ascribed to this fact alone, associated with a low atmospheric pressure; but such influences may be completely neutralized by confinement to in-door occupations, and unwholesome houses.

Climate of high altitudes.—Immunity from phthisis is not complete in any place or climate. Küchenmeister's law ascribes a specific influence to a given height, which varies with the latitude of the place; for every degree of removal toward the south, an increase of 375 feet in height above the sea-level being required to produce the effect. This gives an elevation of about 3,000 feet for the latitude of Switzerland, and of 9,000 feet for the equator. This generalization, however, is contradicted by certain observed facts, and can only have a value as furnishing a suggestive hypothesis. Lombard found that the lower altitudes in Switzerland (from 1,250 to 1,650 feet) had a mortality from phthisis amounting to 10.2 per cent. of the total mortality; the regions of medium elevation (1,725-2,700 feet) had 9.4 per cent.; the high regions (2,700–4,000) had 5.1 per cent., while above 5,000 feet he states that the disease disappears entirely. In the upper Engadin (5,000–6,000 feet), and at Davos am Platz, phthisis is said to be unknown among those who have always lived there. Above a height of 8,000 feet, in the Peruvian Andes, phthisis is almost unknown among natives; while in the coast lands in the same country it is common and rapidly fatal. In the similar climate of the Mexican plateau, in 20°–30° north latitude, immunity is fixed at 7,000 feet by Jourdanet.

Nor is this privilege confined to the natives of these countries; for many most extraordinary cases of cure, even in advanced phthisis, are recorded of these and similar regions, and the statistics of invalids sent to them, as far as collected, are very satisfactory.

In such climates as these, the conditions which seem to be of most consequence are the dryness, the low atmospheric pressure, the clear sky, and the equability. Exposure to atmospheric influences by day and night can be endured with impunity, in our dry western plains: and even in Switzerland the patient can be out of doors a great deal more than would be possible at the same temperature at lower levels. As regards equability (a point which is less needful to the invalid at such high and dry stations), the climate of Santa Fé de Bogota, in New Granada, at the height of 8,648 feet, would seem to leave nothing to be desired, being 59° F. in winter, and 59.5° in spring and summer. The much colder sanitaria of the Alps, which are frequented even in winter by phthisical patients, will illustrate the fact that absolute warmth, in a great many cases, is not essential to recovery; probably it is even detrimental in many.

Dry air and low pressure and abundant sunlight are among the chief curative elements in high altitudes; but to these must be added the fact that the visitor enjoys a freer movement of air, novel exercise, mental exhilaration. In brief, the effects are those of stimulation; and they appear in improved digestion and sanguification, and an increase of muscular vigor.

No doubt the lower atmospheric pressure is of great importance. The Indians of the higher Mexican lands, of the Peruvian uplands, and the natives of certain mountain-districts in India, have an increased rapidity of respiration and pulse, and an enlarged chest-capacity, which seems to be required in order to compensate for the rarity of the air. A rapid increase in the dimensions of the chest has been observed in phthisical English soldiers sent to high altitudes in the Himalayas. This is the most striking of all the circumstances connected with high sites.

This being the case, how can we explain the fact that most excellent results have been obtained in phthisis from sea-voyages? In respect to moisture and pressure, the conditions are completely reversed. The points in common between the sea-voyage and the Peruvian plateau are: the equability, the abundance of sunlight, and fresh air. Both must be called stimulating in their effects; both act powerfully on the appetite and spirits; but these ends are reached by different routes. It may be added that a sea-voyage is better adapted to men than women; that great heat or change is a disadvantage; that an oceanic influence is to be preferred to a mediterranean, and a long voyage to a short one.

As a remarkable instance of immunity from phthisis at a low level, the country of the Kirghis Tartars may be mentioned. These people live on a steppe, a hundred feet below the level of the sea; they number one million; their life is nomadic, and their diet consists largely of "koumiss," or fermented mare's milk.

In further illustration of the variety of conditions under which improvement in phthisis is obtained, the following statistics are given from C. T. Williams:

		PERCENTAGE.	
		Much improved and improved.	Worse.
Sea-voyages to Australia, America, India, China, the Cape, and West Indies	45 winters	89.	5.5
Very dry climates; Egypt and Syria	26 "	65.	10.
" " " Cape and Natal	13 "	58.6	17.24
South of Europe, and Mediterranean Basin, etc.	152 patients	62.5	17.1
Rome	18 "	55.56	33.33
Warm Atlantic Islands, Madeira, Teneriffe, St. Helena, West Indies	70 "	51.43	34.29
Calm moist inland temperate climate—Pau, Bagnères de Bigorre	44 "	50.	45.45

Moist, warm, equable climates, by the sea-side, are decidedly beneficial to catarrhal complaints of the lungs, and also to those of the intestinal tract. In all forms of phthisis, except those of catarrhal origin, such climates are on the whole injurious.

Heating and Ventilation.

General Remarks.

For reasons which will be obvious, it is necessary to treat these subjects together. No system for heating inhabited rooms is admissible unless it includes a provision for a liberal supply of fresh air; and it will be our object, in the following pages, to analyze the methods by which this is done, and to point out wherein some of the most popular of these methods are defective.

We shall here consider the general principles of the subject, and their application to the case of dwelling-houses, schools, and places of public assembly, leaving to other sections of this work the more special conditions which exist in the case of mines, ships, barracks, hospitals, and work-rooms.

Desiderata.—In the larger part of the countries called civilized, man is obliged to provide for himself an artificial climate during several months of the year. We find a good deal of difference of opinion as to what this climate ought to be, among those who enjoy its varied conditions ; even science has not yet said its last word in respect to some most essential points. The following requirements, however, may be regarded as indispensable:

The air provided should be originally pure, or as pure as is possible under given circumstances. In many houses in the country, exposure upon a high site to fresh winds ensures an abundant supply of good air, which cannot easily be kept from entering, even by the process of stopping up cracks in windows and around doors. But in closely built places, and in spots sheltered by hills or woods, the amount of air which enters a house will be lessened by the diminished pressure of the wind. In cities there is a great difference between streets lying on the borders, exposed to storms, and those nearer the centre, where the air is comparatively stagnant. In the latter case much care should be given to the choice of a point for admitting pure air. Most city houses in our climate are warmed by furnaces, which draw their supply from some one opening in the outer wall of the house. Very often this point is chosen as low as possible, commonly on a level with the ground, where the air is apt to be more or less fouled by dust, or by exhalations from gutters, sinks, cesspools, or streets. A close yard, scarcely visited by the sun or blown into by the wind, is often chosen as the source of supply of air. All these faults may be avoided by foresight.

"There are great variations in the quality of air in different cities, arising from density of population, nature of fuel, character and avocations of the inhabitants; and, again, from climate, prevailing winds, and winds at the time of observation, hygrometric condition, normal or abnormal, etc.; but after the dispersion of impurity generated in any particular locality, the purest air is generally found at from 6 to 40 feet, the most impure at 70 to 90 feet above the level of the ground, with a gradation rising to balloon heights. Over any free or open places in a city the dispersion of local impurities is the more completely effected, and the uniformity of condition the more generally obtained; but the elevated air is more impure, when the stratum of diffused chimney exhalations is reached, than it is below."

"Upon a still day, a tower would manifestly offer little advantage in its elevation of the point of taking the air, as regards its purity, unless its height were over 100, and perhaps 200 feet or more."[1]

Perhaps the most common sources of impurity in the house-air are found in the cellars. These rooms are often damp, mouldy, unvisited by sun or fresh air; they often contain the family stores of fuel and provisions, the ash-heap, and other sources of dust or stench. Many persons calling themselves good housekeepers neglect their cellars: a neglect which certainly would not continue if they knew the extent to which the air from cellars tends to rise into the rooms above. No part of the house should be kept more scrupulously neat.

Cellar-air is constantly seeking to pass into the rooms above. This passage is often effected through unintended openings in the hot-air box of the furnace. The duct which supplies the furnace with fresh air often has open seams. The cracks around the cellar-door furnish another route. And finally, after excluding all such obvious means of passage, it appears that air has a strong tendency to rise from any room in a house to the one above it, regardless of doors or flues: it passes in great quantities through floors.

The existence of such upward currents between rooms that do not directly communicate is shown in the experiments of Voit and Forster[2] upon the moisture of the air of school-rooms in Munich.

In a school-house of four stories, they selected a block of four rooms of equal size, one above the other, each opening upon a corridor leading to the common stair. Analyses of the air in these rooms showed that the quantity of aqueous vapor increased quite rapidly from the lowest to the highest. During five days in June the absolute quantity of water (in the form of vapor) per cubic metre of air was found in these rooms, beginning at the lowest, to be respectively 10.5, 11.6, 14.7, and 17.2 grms.: the percentages of saturation were 60, 71, 82, and 94. In this course of experiments the rooms were closed. The only source to which this great excess of watery vapor can be traced exists in the breath and perspiration of the scholars. The atmosphere out of doors, during the period mentioned, contained on an average only 10 grms. to the cubic metre, and its saturation was only 69 per cent. It is necessary to assume that an upward current of air existed in this group of four closed rooms, which, passing from one to the other, received from each an additional charge of mois-

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[1] R. Briggs: Report on the Ventilation of the Hall of Representatives, etc., at Washington.

[2] Zeitschr. f. Biologie, XIII., 1.

ture, until at the top of the house the amount was greater than at the bottom, in the proportion of eight to five. The number and the ages of the scholars did not greatly differ in the rooms.

Of the air which thus freely and constantly passes from cellars into upper stories, what is the probable source? It seems an inadequate and irrelevant explanation to assume that the excess of water and carbonic acid in upper stories (in the above experiment) proceeds simply from the process of diffusion. The conclusion reached by Forster, in another article (Zeitschrift für Biologie, XI. Band), is to the effect that much air enters through the soil. "Currents of air are continually pressing into our dwelling-rooms from the soil on which we live; we are in continual and direct communication with the soil beneath us through the medium of the air."

These remarks are founded upon experiments made in a dwelling-house. Forster caused a large quantity of must to be placed in the cellar of the house, to undergo fermentation, which was completed in a very few days, heavily charging the air of the cellar with carbonic acid. A room on the ground-floor, directly over the cellar, and an adjoining entry, were selected for analysis, and another room on the floor above with its entry. The first simultaneous analysis showed a percentage (parts in 100) in the cellar, at the floor, of 3.049 carbonic acid; in the ground-floor room, of 0.163; in the upper story, 0.108. On the next day, cellar, 0.822; entry on ground-floor, 0.165; in upper story, 0.072; and in the evening, *after a fire* had been kept for some time burning in the two chambers, the contents of the latter in carbonic acid were respectively 0.188 and 0.148 per cent. The rooms had previously been aired out thoroughly; before the analyses were taken they were kept closed and unoccupied during four hours. It thus appeared that the air of entirely unoccupied rooms, containing no sources of carbonic acid, exhibited the presence of this gas in amounts exceeding three and five times the normal proportions; that the amount was greater in the ground-floor than in the upper room; and that an increase, similar and nearly equal, was found in the entries. The effect of heating the chambers, in increasing the percentage of CO_2, was also very marked.

No point in domestic economy is more often neglected than that of absolute neatness in the cellar story. The necessity of such neatness is perfectly obvious, in the case of a house warmed by a furnace, but it equally exists in houses where the cellar is unprovided with this apparatus. In the case of a hospital, it is proper to exclude all kinds of stores from the cellars; nothing but fresh air should be kept in them. In the case of many dwelling-houses, public halls, churches, and schools, it is thought proper to admit air from the cellar to the furnace-box in very cold weather, with a view to economy. In a dwelling-house it can rarely be prudent to do this, as most families must use the cellar for storing provisions.

The opening of the flue for supplying fresh air to the furnace should be high enough from the ground to be out of the reach of mischievous persons, and should be furnished with a grating. It should also have a slide to regulate the amount admitted in high winds.

The dust entering from the street forms a great nuisance in furnace-heated houses. Most of it can be kept out by sifting. This may be effected by letting the air-tube end in a very long bag of cotton-cloth, through the sides of which the air slowly passes into a chamber of supply, communicating with the hot-air box of the furnace.

Scharrath has made trial of a system of purifying the air, which he terms *Poren-ventilation.* In this method the air is driven by mechanical force through the *pores* of a wall of brick or of mortar, which of course intercepts all the particles of dust.[1] This constitutes simply a reinforcement of the natural process of ventilation, which occurs in every house, through the walls, to an extent unsuspected by the inmates. Scharrath, however, seems to have found the practical difficulties of this plan too great, and has substituted for the porous wall a screen of gauzy material, in which the pores occupy less space than the fibres of the stuff. Such screens may properly find a very general application. Few sources of fresh air are so free from dust, or "spores," or carbon-flakes, as to render the precaution needless. The air supplied to the British Houses of Parliament is filtered through a screen, besides being washed by a spray of water. There is manufactured in this country "a fibrous material, made strong enough for hard usage by means of brass wires and a fibre, which excludes dust and still admits air freely." For ventilating railroad-cars, such a contrivance is most desirable.

It is of course desirable to maintain an equal temperature in various parts of the room; and for this purpose it is far better to introduce a large amount of air at a moderate temperature than a small quantity at a great heat. Altogether, apart from the need of fresh air for breathing, it will be found that rooms where the air is comparatively stagnant are apt to be excessively heated at top and cold at the floor.[2] A rapid circulation of air furnishes the best remedy for this very common evil; but the fresh air should be warmed, and not taken directly from out of doors, as is the case in rooms heated only by an open fire.

The air furnished by Galton's stoves is heated to about 80° F. Hot-water stoves (Degen) do not heat the air in the air-space above 45° (= 113° F.). Morin says that "the temperature of the air warmed by hot-water apparatus is always very moderate: it is even difficult to raise it above 100° or 112° with large radiating surfaces. In this respect this method of heating is very healthful, provided that ample ventilation be maintained in addition." Bosc states the proper temperature of the air from furnaces at 30° or, at most, 40° (86° and 104° F.); this should be obtained, if necessary, by causing the air, after leaving the heating-surface, to pass through a mixing-chamber, where any desired amount of cool

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[1] Deutsche Strafrechtszeitung, 1870.

[2] Ruttan, in Canada, stated that in a stove-heated basement-room, over a cold cellar, he has frequently seen the water freeze on the floor when the temperature of the air at the ceiling was 100°, and has often observed a difference of 4½° in the air for every foot of height in a stove-heated school-room, 16 feet high, which was exposed on two sides to the outer air at zero F.

air may be added. Degen's statement is almost identical: the temperature of the air introduced into a room from a calorifère, or furnace, seldom exceeds 40° (104° F.). These statements are certainly not correct in respect to America, where one of the commonest complaints is that of excessive heat. According to Billings, the air is usually at 180° F. when it enters the room.

A great many stoves intended for warming single rooms are very objectionable on account of the excess of heat imparted to the air (*e. g.*, 260° F., and 392° F. in the case of certain stoves described by Morin). There is good reason for supposing that air is injured in some of its properties by coming in contact with metal surfaces at an excessive heat. The nature of the change experienced is not understood; but it is known by experience to be such as to produce in those breathing the air very uncomfortable sensations, as headache, oppression, vertigo. Three considerations may be presented, each assisting to explain the fact.

1. The air contains numerous particles, of vegetable or animal origin, which doubtless undergo combustion when brought in contact with surfaces heated to several hundred degrees. We are accustomed to say that such air has a "burnt smell;" and we recognize something injurious to our comfort. The presence of such gases as originate in combustion without flame, whether on a large or a small scale, cannot be otherwise than harmful to the system, and a tolerance of their effects is hard to establish. It may be further said that such combustion may be expected to deprive the air entirely of its ozone.

2. Within a few years it has become quite generally known that cast-iron, heated to redness, permits a large amount of carbonic oxide gas to pass through its pores; and this fact has given rise to a new branch of industry, viz., the manufacture of stoves and furnaces of wrought-iron, which does not permit of such passage, and which possesses the additional advantage of forming tight joints.

Doubt has been thrown upon these statements by some recent researches published in the last volume of the Zeitschrift für Biologie. The escape of carbonic oxide by the pores of iron is reasonably suspected to be of far less consequence than that which occurs through cracks in the joints of the stove, or furnace, or flues. Hence a real advantage in using wrought-iron with air-tight seams. The point of greatest importance is that the rapid exit of *all* gases of combustion should not be checked in any way, either by a damper in the smoke-flue, or by a cold chimney, or by one which draws irregularly.

3. Air taken from out of doors and warmed for the house becomes comparatively dry. Its moisture is not actually burnt up by contact with the furnace (as is popularly supposed); but its capacity for moisture is so greatly increased by being heated that it appears to be very dry. Thus a cubic foot of air at 32° F. contains when saturated 2.13 grains, troy, of water; at 70°, its capacity for water is 7.99 grains; and if raised from 32° to 70°, without addition of watery vapor, it evidently contains only 27 per cent. of that which it is capable of holding. This dryness is almost uni-

versally considered prejudicial to health; but our views will probably have to undergo some modification upon this point. Every apparatus, it is true, ought to be provided with an arrangement for evaporating water. Experience shows that the result is both agreeable and beneficial; but it is by no means necessary that the air should contain from 50 to 70 per cent. of its saturation-amount of water, though this is required by eminent authorities.[1] The evaporation of so large an amount as would be required, in our climate, would necessitate large and expensive furnaces with great surfaces. A moderate amount of evaporation much improves the air—perhaps owing to the production of ozone in the process.

Surgeon John S. Billings, U.S.A., speaks of this point as follows:[2]

"In rooms heated by warm, dry air, the sensations of discomfort which many persons experience, such as headache, etc., may be relieved by the addition of a small quantity of moisture to the air, for instance, about five per cent.

"At first sight this would seem to prove that the uncomfortable sensations were due to absence of moisture; but nearly the same amount of vaporization is desirable in air heated from any temperature, and therefore varying greatly in the absolute percentage of moisture which it contains. Moreover, in very dry and warm climates, such as that of Arizona, these uneasy sensations are not present.

"It seems to me probable that in the majority of persons these sensations are due to insufficient supply of fresh air, rather than to want of moisture, and that the effects of vaporization in relieving them may, in part at least, be explained as follows:

"In a room heated by hot air from a furnace, or set of steam radiators, all the fresh air for the chamber usually passes over the heated surfaces, and enters the room at an average temperature of 180° F. If the quantity of fresh air required for satisfactory ventilation be admitted at this temperature, the room soon becomes unendurably hot, and to prevent this the amount of incoming air is diminished by partially or entirely closing the register.

"Now, if in front of the register be suspended a porous earthen vessel containing water, or wetted cloths, or a large sponge saturated with water, rapid vaporization is the result; and a large amount of heat is expended to effect this.

"The result is that the incoming air is cooled, and a much larger quantity can be admitted without discomfort. In rooms and passages heated by direct radiating surfaces such as steam-coils, this feeling of discomfort is very common, and is mainly due, I think, to the insufficient ventilation which is usually found in such places.

"I have never myself found it to occur in rooms having an ample supply of air at a proper temperature, however dry the air may have been;

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[1] Wolpert and Péclet state 50 per cent. of relative humidity as the most agreeable; Baring and Parkes about 75 per cent.

[2] Johns Hopkins Hospital: Report on Heating and Ventilation.

but Mr. Briggs[1] and others state that they have so found it, and under such circumstances I can suggest no satisfactory explanation."

Dr. Cowles, in an article upon the ventilation of the Boston City Hospital, published in the Report of the Massachusetts Board of Health for 1879, confirms Billings' statements in reference to the effect of dryness of air. He says:

"I believe that no discomfort has been felt, or ill effects produced, from the low relative humidity [of the air of the ward tested], even on the occasions when there was only fifteen to twenty-one per cent. of saturation. According to De Chaumont, so great dryness is inconsistent with a healthful condition of the atmosphere. Certainly, in this ward, there is uniformly observed a remarkable absence of complaint of any kind that can be ascribed to the condition of the air; and a peculiar feeling of its freshness and purity is frequently spoken of by those who enter the room."

It has been observed that air, which has been charged with vapor in the furnace-box, is comfortable at a lower temperature than dry air, and, conversely, very dry air must be heated several degrees higher than moist air in order to produce a given sensible effect of warmth. Upon these facts the American demand for high temperature may depend. A few observations upon this point may be here made. 1. Moist air, in virtue of the contained vapor, has a greater capacity for heat than dry air. This increases its sensible coolness at a given temperature. 2. Moist air interferes greatly with the radiation of heat from the body. 3. In moist air the quantity of water that can be evaporated from the surface of the body is lessened. 4. The second and third elements preponderating, give to moist air a greater sensible warmth than to dry air of the same temperature. 5. This is modified by the motion of the air. In a moist *wind* the abstraction of heat is proportionably increased; while in a *still place*, as a crowded, unventilated chamber, the absorbed heat is not carried out by removal of the air, and produces great discomfort. The perspiration and the vapor from the lungs assist in producing this effect; the air soon becomes nearly saturated with vapor, unless it is removed by ventilation; escape of heat from the body by radiation is rendered very difficult, and, in addition, every person is surrounded by a ring of bodies giving out equal heat. 6. Whether a given warm dry air subtracts more heat than a given cooler and moister air, is a problem to be calculated for each case separately. As above noticed, a very moist wind is chilling, a very moist still air is stifling, and prevents escape of heat from our bodies.

Some remarks by Robert Briggs[2] are here in place:

"The effects of a nearly saturated atmosphere differ with the temperature altogether. Such an atmosphere at from 35° to 50° is found to be intolerably chilly; and though evaporation may be checked, and this loss of heat be removed, yet the conductive and radiating value of the

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[1] On the Relation of Moisture in the Air to Health and Comfort, Journal of the Franklin Institute, January and February, 1878.

[2] Relation of Moisture in the Air to Health and Comfort.

vapor in the air is now elevated enormously." (The surface of the body, in a misty, cold air, is chilled by direct contact with the mist, in the same way as if it were in contact with wet clothes.)

"Passing upwards in the scale of temperature, from 50° to 65° the point of equilibrium of cooling action by conduction or radiation of vapor in the air, with supply of heat from checked evaporation of the skin or lungs, . . . seems to be reached." . . .

"From 65° to 80°, a saturated atmosphere is sultry and oppressive. The surplusage of heat cannot be removed by conduction; and the natural effort of the system is to produce evaporation." (Lassitude of this condition, as contrasted with the stimulant effect of the air at 50°–65° in the moist English climate.)

"We have in the Northern United States about five months of the year when the temperature ranges from 0° to 50°, and, consequently, when our civilized avocations demand artificial heating. The winter climate of the Eastern, Middle, and Northern States is one of great vicissitudes, with extremes, both of temperature and of hygrometric conditions, following each other rapidly. In the Northwestern States it seems that a somewhat greater uniformity of temperature, and a much more uniform hygrometry exists during the winter months; but in the Middle-Western States the irregularities appear to be as frequent as in the Eastern States. Except that the length of the winter season is a little cut short, and the excessive cold is a little alleviated, in the southern portion of the belt of country I have designated, much the same phenomena of climate exist all through the States north of the 40th parallel of latitude. Throughout this territory it has become recognized that the minimum temperature of comfort for heated and ventilated rooms can be stated at 70°, with an admitted, and generally supposed inexplicable, if not unreasonable, demand for 70° to 78° in some localities and at some times."

This writer is disposed to lay very great weight on the hygrometric condition of the air in the United States as a cause of this desire for a high temperature. It is right, however, that, in considering this cause (which is undoubtedly a real one), we should also remember that we Americans are delicate by habit; and that, when first established in England, an American visitor complains of the temperature which suits the English. A German in England makes the same complaint. Further, it may be suggested that a lower temperature would be found comfortable in a house, if the walls were made thicker and the windows double; for our sensations depend largely on the temperature of the walls, rather than on that of the air we are in. And in American cities, persons accustomed to being out of doors, and young persons, are apt to suffer from the prevailing taste for hot rooms (especially marked among the aged), just as a newly arrived Englishman suffers.

The watery contents of the air of a room often condense on the windows, and even on metal, ceilings, or roofs, causing in some cases serious damage to books or other property. A double window may remedy this trouble to a great extent. In the case of a glass roof, the same means is at hand; but the space between the two glazed surfaces will have to be warmed by an apparatus specially intended for it. This troublesome necessity is much less common in the United States than in Europe. The writer is acquainted with one instance, that of the State Library in Boston, where the roof dripped with condensed moisture, and the windows had to be provided with gutters on the inside. This condition was partly due to the constant escape of vapor from the heating-apparatus, through a leak designedly left unclosed; it has been remedied, as regards a part, by sheathing the copper roof with a wooden ceiling.

The temperature of the air introduced for the consumption of a household ought, in mild climates, to be nearly the same as that desired in the rooms. In cold climates, like those of New England or North Germany, the loss of heat from the walls, roof, and windows produces so rapid a cooling within, that a much higher temperature is required. This cooling, again, is largely dependent on the material of the walls and their thickness, the presence of numerous single windows, and, still more, upon the force with which the wind strikes the side of the house. "If the room has large glass surfaces which cool the air, if there are not many occupants or lights, the fresh air should be warmer, and its temperature may be as much as 86° or 95°." (Morin.)

To illustrate the cooling effect of glass, let us take the statement of Mr. Hood,[1] who shows that one square foot of glass will cool 1.279 cubic feet of air as many degrees per minute as the internal air exceeds the external in temperature. Suppose the thermometer to stand outside at 15°, inside at 65° = a difference of 50°. The room, of ordinary size, may contain 3,000 cubic feet of air, and have two windows, with a surface of glass equal to 30 feet. The cooling effect produced will be equal to lowering the temperature of 1.279 feet of air, in one minute, 50 × 30 degrees; or one foot of air 1.279 × 50 × 30 degrees = 1918.5°. If occupied by six persons, the air of the room should be renewed at least once in fifteen minutes, during which period the total cooling effect will equal 1918.5° × 15 = 28,777.5°, which, when divided among 3,000 cubic feet, represents a constant lowering of temperature in the general atmosphere of the room, equal to 9.5°.

As regards the temperature most suitable for rooms, the following statements represent the existing differences of opinion among scientific men:

Normal temperature of public school-rooms in Munich,[2] 15° R. = 18.75° C. = 65.75° F.

In the schools of Vienna,[3] "14° R. is regarded as the correct height of the thermometer" = 63.5° F.

A temperature of 14° R. is "quite comfortably warm in winter, after the walls of the house have been thoroughly warmed."[4] Pettenkofer says that 14° R. is "sehr behaglich warm"—very comfortable.

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[1] Warming and Ventilation.

[2] Voit and Forster.

[3] Ber. über österr. Unterrichtswesen (Exposition of 1873), Part II., p. 579.

[4] Geipel, l. c.

The hall of the crèche of St. Ambrose,[1] Paris, was heated to 16° C. = 60.8° F.

Morin[2] gives the following table:

"In well-ventilated places, with a constant change of air, higher temperatures can be easily borne, and even be found pleasant, than those which would be found oppressive where the air is not changed. Nevertheless, the internal temperature should not be kept above the following points:

"Nurseries, asylums, and schools	59°
Workshops, barracks, prisons	59°
Hospitals	61–64°
Theatres, cafés, lecture-halls, etc	66–68°"

The interior of the church of Saint-Roch, in Paris, was raised to the temperature of 16° (16° R. = 68° F.); it even rose above 18° during crowded services on Sunday. "This temperature" (72.50°), says Péclet, "is insupportable in a place where people sit in their outer garments, and many of the congregation were obliged to leave the church." An American congregation would not have been greatly annoyed by this heat.

In the quarters of the cadets of the Bavarian army the temperature is ordered not to fall below 14° R. nor rise above 16° in winter (= 63.5°—68° F.).[3]

The Department of Religion and Instruction in Würtemberg, under date of December, 1870, orders that "the temperature in each schoolroom, during the entire session, at the height of [say 4 to 5 feet] above the floor, must not exceed 16° R., as a rule, and should be rather lower than higher, but must not fall below 13° R." [respectively 68° and 61.25° F.]. The same range is prescribed in the public schools of Saxony.

The average temperature of the air at the head of the beds in the new surgical ward at the Boston City Hospital, taken at 7 A.M., 2 P.M., and 9 P.M., for a week, was 68.3° F.; the air was considered eminently satisfactory. Five observations upon the humidity of the ward, at various dates, in and about the same period, gave percentages of saturation = 21, 26, 27, 48, 23.

Surgeon D. L. Huntington, in reporting upon the Barnes Hospital of the Old Soldiers' Home at Washington, says that a "pleasant, even temperature of about 70°" is maintained in the wards.

H. I. Bowditch, in the Fifth Report of the Massachusetts Board of Health, says that "in the sitting-room the air should not be above 72° F., nor below 68°; 70°, the medium, is the best."

There seems, therefore, to exist in America a preference for considerably higher temperatures than are desired in England or on the Continent. This may have various explanations. A very variable climate, with abundant means for paying for fuel, induces us to heat our houses constantly

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[1] Degen, op. cit., p. 95.

[2] Smithsonian Report, 1873.

[3] Roth und Lex, op. cit., p. 166.

at a rate which is only suitable in the coldest weather. A sudden rise of temperature from 10° to 40° or 50° F. is of frequent occurrence in many parts of the United States during the winter; the effect of which is that the house is rapidly over-heated, and those who inhabit it have to suffer for a while. These changes predispose to delicacy of the skin and mucous membranes, and, taken in connection with our habits of keeping in-doors, go far to account for the national liking for a high temperature. The remedy for this abnormal condition may be found in the systematic training of children to spend long hours in the open air and in the regulation of school-habits. It is perfectly feasible for an American family, living in a very changeable climate, with young children, to accustom itself to a temperature of about 60°–65° F. Several such cases are known to me, one of which I will mention particularly. The writer quoted is Arthur H. Nichols, M.D., of Boston:

"As regards your inquiry, we have continued to maintain a temperature of 58°–60° within our house, and with the very best results, and I would on no account be induced to go back to the high temperature of 68°–70°, usually thought necessary in winter. Children thrive under these conditions from the outset; but adults, especially those with whom the circulation has become somewhat sluggish, usually require warmer clothing than if the temperature were higher. Among the advantages of this lower in-door temperature are, first, the body is hardened and tone is imparted to the whole superficial integument; hence the system is subjected to a less severe shock in going into the open air, and the constitution being less susceptible to the influence of cold and atmospheric changes, less clothing is required when out of doors, and the numerous petty ailments attributable to the effect of sudden 'colds' (sore throat, acute nasal or bronchial catarrh, catarrh of the frontal sinuses, acute rheumatism, etc., etc.), which are commonly regarded as inevitable concomitants of the winter campaign, are absolutely and finally done away with. A low temperature stimulates the appetite, whereas a relatively warm air tends to derangement of the digestive functions and impaired nutrition.

"To avoid subjecting my own children to the insanitary conditions of school-rooms, I have been obliged to establish a school for twelve children in my own house. The school-room is necessarily rather small and low-studded, but, being furnished with a capacious open fireplace, the air never becomes perceptibly contaminated, and there has never been any complaint of coldness on the part of the children.

"I am of opinion that the system is better prepared for sustaining a low temperature within doors by the habitual indulgence in a bath of cold water in the morning." It is added that "when children come in with wet feet, an immediate change of socks and shoes is requisite, the more so because in a cold house the feet would otherwise with difficulty become warm. The above views are the result of an experience of ten years."

Apparatus for Heating.

An absolute requisite in respect to an apparatus for heating is that it should deliver an abundance of air of the best quality free from contamination. A moderate temperature, usually implying a large heating-surface, is a desirable point. Capacity for powerful action on very cold days is necessary in our climate; capacity for diminished action is very much to be wished for. Safety against fire, economy, simplicity, facility of application to varying conditions, rapidity of action—all require attention in the pages to follow, in which the subject will be divided under the heads: Chimneys, Fireplaces, Stoves, Furnaces, Steam-heating, Hot-water Apparatus.

The Chimney.

This structure is composed of a *shaft*, a *cap*, and a *throat*.

The *shaft*, or main body, is usually of masonry, and hence assumes a square, or nearly square, shape in transverse section. If masonry be used, the section should not be in the form of an elongated parallelogram. Such a form exposes the contents at the sides of the chimney to a great cooling action, which assists to form columns of descending smoke. A square aperture is less objectionable. A round section, however, is certainly best, as equalizing the current, and reducing friction to a minimum. Such chimneys may be made by placing common glazed earthen-pipes within a square brick chimney; the triangular spaces left at the four corners may be utilized for water or gas-pipes. Morin has given figures of moulded bricks or tiles, such as are used in building cylindrical shafts in Paris, but it is unnecessary to insert them.

The transverse section remains the same throughout the shaft in most domestic chimneys. In some special cases there may be advantages in enlarging the size toward the top.

The size of the shaft may easily be calculated from the quantity of air expected to pass and the velocity. The latter should not exceed two metres per second (say 6½ feet); an excessively rapid discharge is wasteful of heat. The quantity to be discharged may be assumed as equal to five times the cubic contents of the room to be heated, in the case of an open fire; under other circumstances it varies very much.

The *cap* is designed to fulfil two objects: protection against wind and rain, and assistance to the draft. The former object is attained in a great variety of ways; the latter is perhaps not attained at all in any direct sense.

If the chimney is built square or oblong, or even if cylindrical in section, a symmetrical narrowing at its top (see Fig. 1) will help to prevent the irregular descent of cold air, especially when the fire is low; and such a constriction is quite commonly found.[1] Other appliances, in great number,

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[1] A velocity of 3 metres at the chimney-cap is usually assumed as sufficient to draw off the smoke; this rate is very undesirable in the body of the chimney, where 2 metres should not be exceeded. (Degen.)

have been invented, of which a few are here given, showing some of the chief ways of keeping wind or rain from penetrating. One of the simplest devices consists in covering the top with a plain flat roof, and piercing its sides just below with upright oblong holes (Fig. 2). Fig. 3 gives, in one view, two modes of closing the cap. Fig. 4 shows, in a modified form, one of the most widely applied principles. The cylindrical tube of

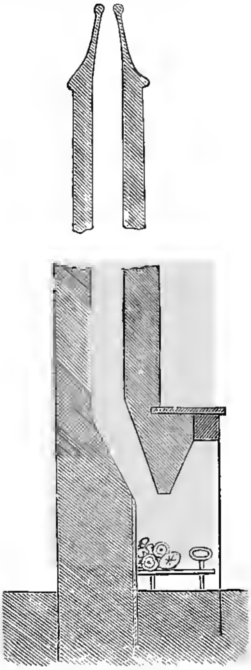
Fig. 1.—Section of chimney, showing equal calibre of shaft and constriction of cap and throat.

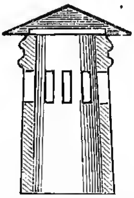
Fig. 2.—Section of a chimney-cap; the smoke passes out at slits in the masonry of the chimney. (Bosc.)

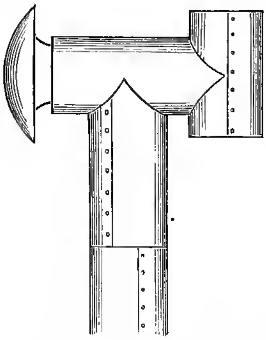
Fig. 3.—Two methods of protecting a flue against the entrance of wind. (Péclet.)

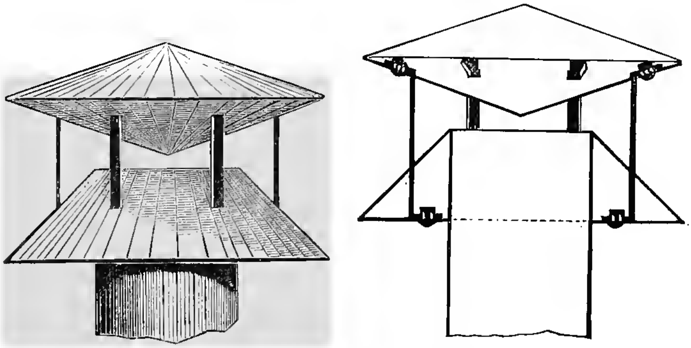
Fig. 4.—Van Noorden's chimney-cap.

the flue is furnished with a collar of metal, slanting downward and outward; and above this, at a suitable distance, is fixed a cover, which sheds rain and prevents the entrance of downward currents. This upper piece is usually flat, and serves no purpose except the interception of rain and direct currents of wind. In the form here given, it is believed that the lateral blasts of wind are neutralized, or even made useful in promoting the draught of the chimney. The effects of inclined surfaces are often paradoxical. In some models, as in Fig. 5, the breath directed perpendicularly down upon the cap, or horizontally, will cause a rapid ascent of the air in the tube. Nothing would seem more desirable than such a result; but, in point of fact, it is very questionable if it is really attained in working chimneys. We can be sure of protection against descent of wind, but cannot positively state that the draught is augmented by any form of these caps that has yet been tested.

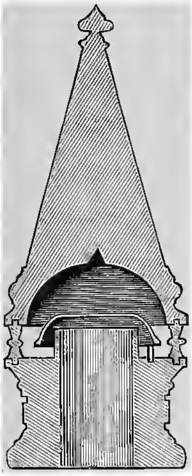

Fig. 5.—Section of Mihan's tower-ventilator.

The swinging-cap (Fig. 6) is represented as pivoted at a single point. In calm weather it takes the position indicated by the shaded design; when the wind blows from the right to the left, its position is given by the dotted lines.

Fig. 7 gives another movable cap. The vane keeps it always pointed so as to receive the wind in its tunnel-shaped expansion (at the left of the cut). This wind leaves the nose of the tunnel in a jet which, in its motion, exercises an influence of traction upon the surrounding column of air in the flue.

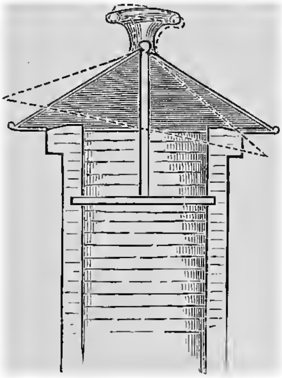

Fig. 6.—Swinging-cap. (Bosc, Péclet.)

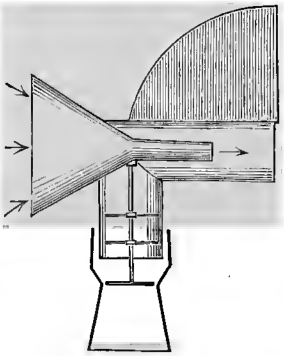

Fig. 7.—Cap to accelerate draught in a flue. (Péclet.)

The throat of a chimney is the portion leading to the fireplace; it is made quite narrow to insure against the occurrence of back-draughts and the escape of unwarmed air into the shaft. Speaking generally, the velocity of the air passing through the cap or the throat, though, of course, not constant, may be calculated at three metres (say ten feet) per second.

The purposes of a chimney are two, viz.: 1, to remove the products of combustion; 2, to assist in ventilation. A chimney may be built for either purpose, or may effect both at once.

The column of air contained in the shaft of a chimney may be considered as balanced against another column of equal dimensions and height outside of the chimney. Each of these columns, in addition to its own weight, supports the weight of the superincumbent atmosphere, equal to a pressure of 14.7 pounds upon the square inch; but the latter is equal for both columns, and may be disregarded. If, therefore, the weight of the air in the chimney is equal to that of the column of outer air, the two columns are in equilibrium, and no movement occurs. But if from any cause the air in either column is heavier than that in the other, the heavier will descend and force the other upward. Such a cause of increased weight is found in the cooling of the air; while diminished weight, as a result of expansion, is a characteristic of warmed air.

Upon a hot day, in summer, a cool chimney will often "draw downward," as we say, *i. e.*, its cool, heavy air will sink and escape by the fireplace into the lighter air which surrounds it. If a considerable portion of the chimney is accessible to the heat of the sun, its upper portion may become so heated that the total weight of the column of air (taking the upper with the lower portion) becomes less than that of the same bulk of outer air, when it rises—or, to speak correctly, is forced upward by the heavier outer air pushing inward at the fireplace.

The height of a chimney, abstractly and separately considered, has nothing to do with the draught. A tube 5,000 feet high will contain rarefied air at its upper part; but such air will not necessarily ascend, or be forced up, for its counterpoise is a column of air in just the same state of rarefaction. Nevertheless, in practice, a tall chimney is much more apt to draw well than a short one, even if there be no fire. Tall chimneys stand clear, receive the full rays of the sun, and are not exposed to those irregular gusts of wind which are so annoying in the case of low chimneys. And if a chimney is warmed, it is evident that an increased height is equivalent in result to an increased difference in the weight of the two columns of air—or increased pressure at the fireplace and improved "draught." For the latter reason, we find that when one flue is pierced with several openings for fireplaces, in different stories, the draught is much greater at the lower than at the upper openings.

Bad draught.—A few of the causes of this troublesome complaint may be enumerated as follows:

A flue that is too wide is apt to be imperfectly heated; the smoke tends to adhere to one side, while a counter current of colder air descends on the other side. A special funnel or flue of a proper size should be provided.

If the throat is too wide it carries up a quantity of cool air, preventing the warming of the chimney.

A flue that is too small is not a frequent fault. For an ordinary room a circular funnel of the diameter of six or eight inches is sufficient. A square flue need not exceed twelve or sixteen inches in diameter.

The use of wet fuel may throw into the chimney a quantity of heavy smoke at a low temperature, which does not easily pass off, nor sufficiently heat the masonry.

A chimney without a fire will sometimes suck down the smoke from a neighboring chimney-top. Or smoke may enter a room from the fireplace of another room, if both use one chimney in common. For these cases close valves may be used.

A deficient supply of air to the fireplace is a common fault. The doors and windows, especially in modern houses, often shut so tight as almost to prevent the ingress of air, at least in quantity sufficient to support the combustion of fuel. In round numbers, 1,000 cubic feet of air are required to burn one pound of wood.

The direct rays of the sun striking on a chimney often make it smoke. This is apparently in contradiction with what has been said above, but may perhaps be explained. A large chimney would naturally be more inclined to smoke in the summer, when imperfectly heated, and this would coincide with the period of sunshine. Or, the sun may, by warming only one side of a chimney, produce a disturbance of the currents of smoke within, with a tendency upon the cool side to sink.

A chimney may be too short to draw powerfully. And, further, such a short chimney, often found in the addition or L of a house, may have its action inverted by the more powerful draught of a tall chimney in the main part of the house. A staircase leading straight to the top of the house may contain such a heated atmosphere as to act like a chimney, and similarly interfere with the action of short chimneys.

The remedy may consist in shutting doors so as to isolate the chimneys from each other.

Two fireplaces in one room are very apt to interfere; in fact, it is very hard to avoid this, unless one be closed with a trap or valve.

The effect of wind striking downward upon the chimney may be neutralized in some cases by properly made caps. But the chimney may be so situated in an angle, overlooked by high walls, that the wind coming from a certain direction is condensed in the confined space, and necessarily seeks an outlet down the flue. This should be remedied by extending the flue or chimney above the level of surrounding buildings.

FIG. 8.—Gust of wind entering chimney (Wolpert.)

The effect of wind striking upon an *unprotected* chimney is well seen in Fig. 8, where the wind forms a whirl or vortex at the top.

This by no means exhausts the list of causes, but comprises the principal.

Fireplaces.

By this term we shall intend what are commonly called "open-fires." They scarcely require description.

The open fire is one of the most agreeable ways of heating a room, on account of its cheerful look. In houses already warmed to some extent by a furnace, stoves, or kitchen fires, they furnish a most suitable addition to these arrangements.

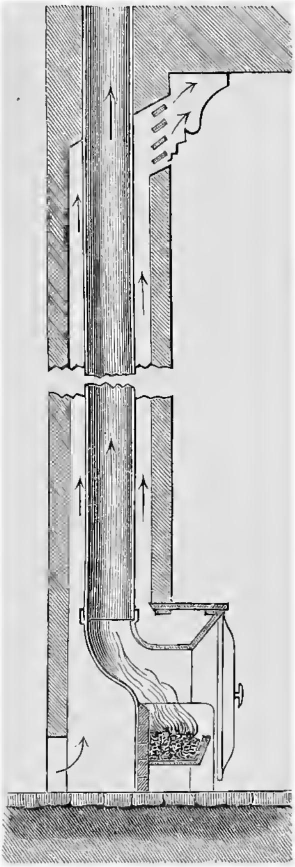

FIG. 9.—Section of the Galton fireplace and chimney.

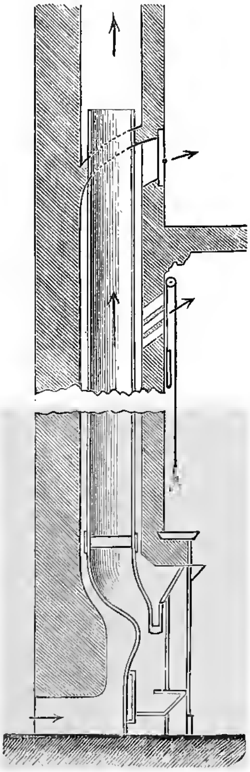

FIG. 10.—Another form of the Galton fireplace, in which part of the heat is employed to warm an upper room.

An ordinary fireplace renews the air of the room it warms on an average four or five times in an hour. (Degen.) This has given rise to a rather indiscriminate praise of their virtues as ventilating agents. It is perfectly true that they may easily draw from 10,000 to 20,000 cubic feet of air per hour; but they do not do it in a scientific way. To supply the large demand, air enters from all the adjoining rooms; the kitchen, cellar, water-closet, often discharge their air with the greatest rapidity into rooms which, thus heated, are converted into huge air-pumps. From the other side come currents through the window-cracks, which are felt in the form of annoying draughts, and chill the floor, so that a person sitting at a good open fire is often "roasting on one side and freezing on the other." In fact, the larger part of the ventilating effect is applied to the lowest layers of air—those situated within three feet of the floor—while the upper regions remain comparatively stagnant. The cold air from the windows naturally seeks the floor at once, and passes straight to the fireplace. This may readily be shown in a room in which the windows are placed on one side of the fire; the smoke of a cigar held before the fire at the distance of a foot, on the side toward the window, being drawn in with rapidity; while if held toward the other side, it does not even enter the fireplace.

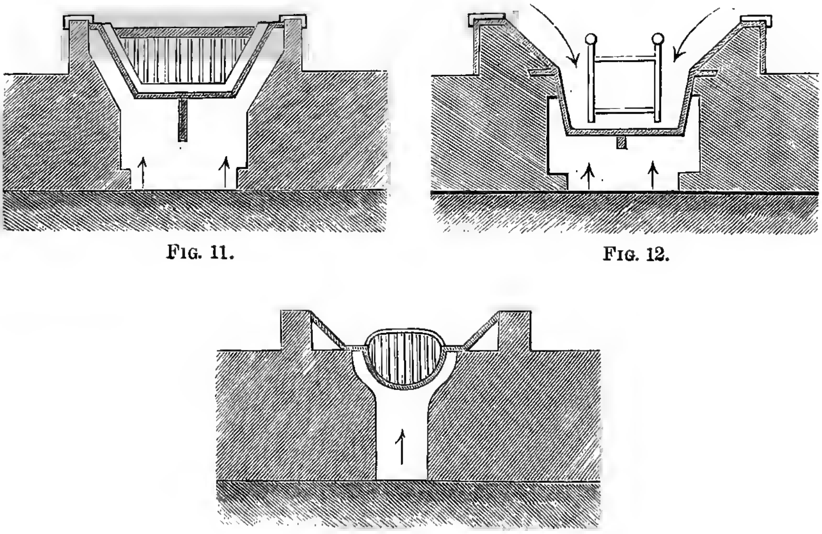

Fig. 11.

Fig. 12.

Fig 13.

Figs. 11, 12, 13.—Forms of Galton's hearth in horizontal section.

Another objection to the open fire lies in its wastefulness, only 12 or 14 per cent. of the heat generated being utilized.

Both these points, however, have been successfully met in the so-called ventilating-stove, the principle of which was used by Franklin, although it has been lately revived under the name of Douglas Galton and others. These stoves (Figs. 9–13) all possess some form of false-back, behind which is an air-space communicating with the outer air by a pipe in the floor, and with the air of the room by suitable apertures or registers near the mantelpiece or the cornice. They supply to the room a large quantity of *fresh warmed* air at a moderate temperature; and the supply thus furnished is sufficient to prevent that annoying leakage through cracks and doors.

The air enters in a mass with some velocity, and in considerable volume; it is introduced above the level of the fire—all of which circumstances aid in producing a quick circulation and a disturbance of the whole mass of air in the room, with consequently a comparatively equal temperature.

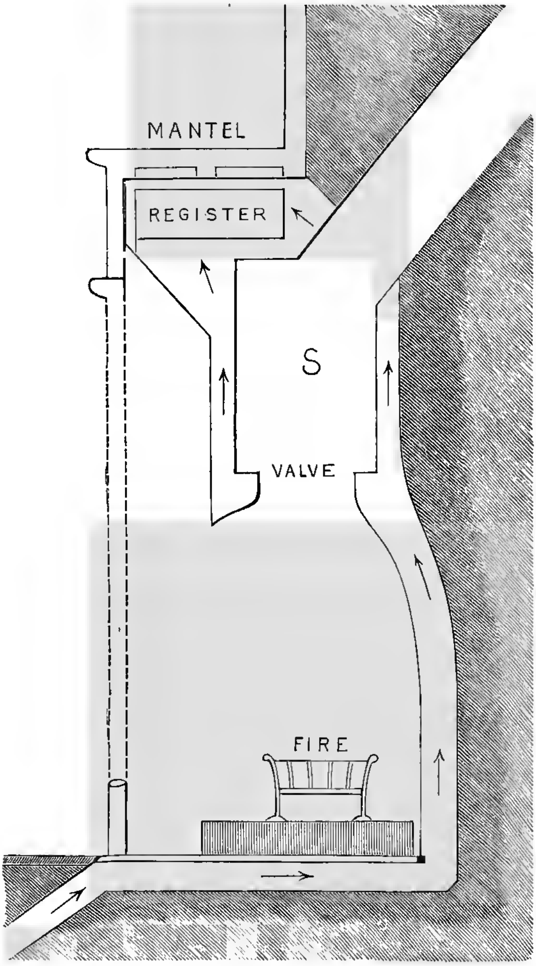

FIG. 14.—Section of a ventilating stove—the "foyer Joly." (Bosc.)

Of Galton's stove it is stated that it brings in about the same amount of air as escapes through the chimney, and at the temperature of about

80° or 90° F. The amount of heat utilized was found to be three times as much as in the case of a common grate, viz., 35 per cent.

The Galton grate is given in Figs. 11–13, in horizontal section, showing the direction of the current of fresh air striking against the iron back of the stove. In Fig. 9 is seen how the air, having passed over this surface, is further warmed by contact with the heated flue, in a long, upright chamber—the chimney, in fact—and enters the room by apertures at the cornice. In Fig. 10 it is seen how the room above may be warmed from the same source at will. In each case the fire is visible, and gives out the same amount by direct radiation as in an ordinary grate.

Fig. 14 represents another simple form of ventilating-stove, in which the smoke from the grate is received in a large sheet-iron box, S (about four feet long in the horizontal direction), around which currents of air, introduced by a channel under the hearth, play, and finally enter the room by registers.

In another design the air is warmed in its passage through upright cylindrical tubes, which discharge into a box; the latter opens into the room by perforations in the iron ornamental work around the fireplace. The smoke passes between the cylinders before reaching the chimney.

The popular "Fire on the Hearth," an American stove, is of the class of ventilating-stoves. It draws its air from out-of-doors; but the duct is provided with an opening, in the form of a ring, just above the floor, through which some of the air of the room may be sucked in. If this is the case, the ventilating power of the stove is of course lessened.

The ventilating-stove ought entirely to supplant the present wasteful and comparatively unwholesome open grate, popular and useful as the latter has been.

It is often and justly remarked that ventilation always costs something. And as the old-fashioned grate costs enormously, it is supposed to give us the very best ventilation—a method of reasoning which involves a logical error. It has already been shown that the result is not a thoroughly good one, even with all the outlay. And, as regards the new system, two remarks are pertinent. First, it does work well, and does not take away enough heat from the chimney to check the draught; it therefore only utilizes what would otherwise be wasted. Second, it feeds the fire with warmer air, thus in part restoring to the chimney what it borrowed.

The temperature of the gases in the chimney, arising from the combustion of fuel in an open grate, is given by Degen as usually exceeding 212°. The heat required to be maintained in the chimney may be ascertained by adding 30° or 40° C.[1] (= 54° or 72° F.) to the temperature of the room—say 120° to 138° F. The difference between 212° and 138° may be considered as wasted by ordinary grates.

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[1] According to Herter, 20° or 30° C.

STOVES AND FURNACES.

1. *Direct and indirect heating.*—There are two chief ways in which heat is imparted to the air and other contents of a room, namely: radiation and convection. Both processes are almost always going on.

Between any two bodies of different temperatures not separated by substances which prevent the process, a transference of heat is constantly taking place from the warmer to the colder by radiation. The burning coal and flame in a grate radiate heat to the walls, furniture, and persons in the room; persons radiate heat to the walls and other objects; the walls radiate heat to the windows in cold weather.

The amount of heat absorbed by dry air in a room, from rays which pass through it from a stove or open fire, is too trifling to be considered. The process of warming a room which has become thoroughly cold consists in the transfer of heat *to its walls*, and the gradual elevation of the temperature of the latter until it equals that which is desired for the air of the room. The walls and other solid objects form the reservoir of heat; the air, changing every ten or fifteen minutes, should also have a certain warmth; but the sensation of chilliness is far more troublesome when the walls are cold than when the air is cold. This fact is made the basis of some systems of warming, by means of heated floors or walls. It is well known that the Romans heated their bathing-rooms by the floors, which were of hollow masonry, containing flues for the escape of the products of subterranean fires.

A stove will heat the air in a moderate-sized room in a few minutes; but no degree of heat in the air makes it safe to remain seated until the walls are also warmed. In our climate, dampness is less to be feared than chilliness of the walls; and the latter is not an uncommon cause of illness. A damp wall, however, is worse than a dry one, as taking up much more heat (latent condition) and protracting the period of warming. Wooden or papered walls, also, abstract heat from the body less rapidly than stone and brick walls.

A parallel to this exists in the case of light, which is of most value for every-day purposes when it does not shine directly upon the object to be illuminated. For instance, in reading we prefer the light reflected from the sky or the white ceiling. A room with cold walls and a hot stove is comparable to a room with dark-tinted walls and a lighted chandelier.

The heat of the walls can be imparted to the air by convection. As elsewhere stated, this is the principal way in which air warms itself by contact.

In respect to its action upon the temperature of a room, a stove resembles an open fire, in that both radiate heat. A stove heats also by contact, however; and such is the force of association, that we imagine this method of heating to be less agreeable than that by direct radiation. The fact is, that air heated by contact with *moderately* warmed surfaces, as the German or Russian stove, has an extremely pleasant quality. The popular fondness for an open fire is based on its pleasant aspect and its power of evacuating air from the room. For when radiation is powerful, without renewal of air, it is almost universally regarded as a nuisance, and screens are put up to protect the body.

A hot-air furnace, with its air-box, is analogous to the case of a stove standing in a room. The furnace radiates heat to the walls of the "box," which are usually of masonry; and the air becomes warmed by contact with the surfaces both of the furnace and of the box. If the stove or furnace is not too hot, and the air is freely changed, the effect is pleasant. Air warmed by a soapstone furnace, and transferred by a pipe to a room, is very like air warmed in the room by a porcelain furnace.

2. *Heating-powers.*—In general, a heating-apparatus either acts rapidly, becoming quickly hot, cooling quickly, and giving a great heat in proportion to its size; or else it acts slowly, and requires to be of a large size in order to produce a due effect, while it retains its heating power for a long time. Apparatus of the former class is usually held to be objectionable, as has been already stated.

It is certainly well to have a larger stove or furnace than is actually needed, and to keep a moderate fire. This is true, whether the room is heated directly or by registers. Certain forms are so liable to overheating that they deserve universal condemnation; such a form is the little cylinder or sphere of cast-iron, with strong draught and quick combustion, rapidly growing red-hot by direct contact with the glowing coals. The use of iron need not, however, be proscribed: it can be protected in two ways from over-heating. An outer casing of iron, with secure joints, so placed as to leave a stratum of air between the fire-box and itself, will effect the object. The "base-burner" stove is thus protected. Better still is an inner lining of fire-brick[1] or earthenware, which prevents the burning coal from coming in direct contact with the iron, and which ought never to be omitted in stoves or furnaces.

Overheating of air in furnaces may be prevented by providing liberal channels for the passage of air through the hot-air box, and correspondingly large apertures for its escape from the rooms. Thus large quantities of air are drawn through, and do not have time to acquire a great heat. In very cold weather the occupants of rooms insist on having air at a more elevated temperature than usual; this is commonly attained by closing the cold-air box, and lessening the flow of air, but should rather be effected by calling into action the reserve force of the furnace, which should be large and powerful enough for cold as well as moderate weather.

The Russian stove is the type of a slowly-heated and slowly-cooled apparatus. These stoves are of great size, and are built at the same time with the houses. They are rectangular masses of brick-work, pierced with vertical canals, which conduct the smoke and consumed air several times up and down through the structure before reaching the chimney.

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[1] Despretz states that the conducting power of brick-clay is only $\frac{1}{34}$ of that of iron, or as 11 to 374.

They are usually two or three metres high (six and a half to ten feet), and occupy a horizontal surface of one and a quarter square metres. A very strong fire is made in the morning, and when the wood is wholly converted into live coals, the door of the fire-box is shut and the valve of the chimney almost shut. The warmth is retained by the mass for a very long time, and the chamber is kept agreeably warm for twenty-four hours without fresh firing.

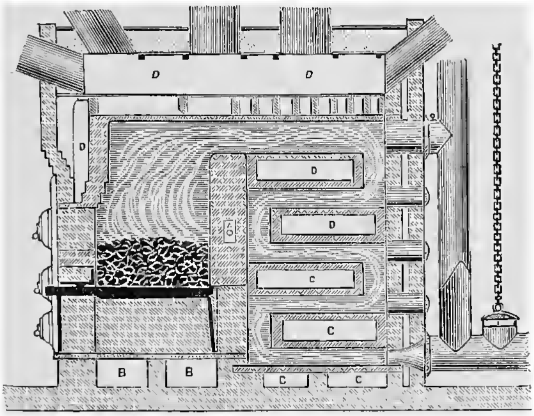

FIG. 15.—Soapstone furnace. B, C, D, passages for warming fresh air. The draught at starting is upward; after the furnace is warmed, it is led down by a circuitous path to the funnel.

The porcelain stove, so great a favorite in Germany, is essentially similar in principle, though of smaller dimensions.

In France, furnaces are made of hollow bricks, which, when built into a wall, form channels for the ascent of fresh air. The heated smoke is caused to pass repeatedly over the outer surfaces of these bricks, and in so doing warms the ascending columns of air inside, which are finally collected in a reservoir or box for distribution.

A somewhat similar furnace is made in this country of slabs of soapstone, and is highly praised for the purity of the air furnished. It occupies a much larger space than an ordinary iron furnace of equal power. The joints can be made very close with this material.

3. *Quality of air.*—Under this head it is proper to speak of the contamination of air by products of combustion. The latter may escape from a stove or furnace of any description, when the "damper" is too close. By the term "damper" I mean a valve in the chimney or smoke-flue, which is capable of nearly or quite closing the aperture. No valve of that sort should ever be placed in the smoke-passage of an apparatus in use. The necessary checks to excessive draught should be applied at the point where air *enters* the fire, not where it *leaves* it. The joints of any given stove are presumably somewhat pervious, and through such joints, the moment the smoke-outlet is closed, gases begin to pass into the room. On the other hand, a stove made as close as practicable by shutting its

doors, still leaks *inward* a little, allowing a sufficient supply of air to reach the fire.

The draught of a flue is much dependent on its size.

A contrivance, often applied to the smoke-flue of a stove or furnace, consists of an aperture for the admission of air to the flue from the room, and its object is to diminish the draught without obstructing the passage of smoke. It is a serious objection to this contrivance that it is liable to cool the flue too much; furthermore, it greatly lessens the atmospheric pressure on the stove, which constitutes our chief safeguard against the escape of gases.

In the case of hot-air furnaces, it is very desirable to make the seams actually impervious to gas. This cannot be done with the ordinary materials—cast-iron, putty, and red-lead. The unequal contraction and dilation of pieces of casting inevitably cracks the putty or cement—a matter of small moment, provided we were sure of a constant atmospheric pressure inward. But we cannot be sure that such a pressure will continue under all circumstances; and the manner in which the direction of the pressure may be reversed is easy to understand. For the iron wall of the furnace represents a diaphragm between two boxes, from each of which a powerful current ascends. One of these boxes is the stove itself—discharging into the chimney. The other is the hot-air box or reservoir—discharging through pipes, registers, halls, and stairways; all of which taken together may form a kind of rival chimney, drawing upon the hot-air box with a force nearly or quite equal to that of the actual chimney. Then the direction of the wind may be such as to favor the exit of air from the box, by the duct intended to admit it; and if, under these circumstances, a puff of wind strikes the chimney unfavorably, it is not strange if the pressure should be for the time reversed, and gas escape into the box. In point of fact, this not rarely happens in furnaces of cast-iron. A suitable material for avoiding this exists in wrought-iron, which can be made perfectly tight by overlapping, riveting, and hammering the edges. Stone furnaces can be made tight also.

When the door of a furnace is opened, a puff of gas often escapes, proving that the flue is not drawing well, even if well constructed. The matter is made worse by shovelling in coal, causing sudden displacements of air from the fire-box. This escape is soon perceived in the rooms above. It is very desirable that the cellar should be ventilated in some way independently of the upper stories, to carry off such accidental products. The hot-air box and the duct which takes air in should be made tight, to exclude gas and other components of cellar-air. The supply of air for the fire and that for the air-box ought, in short, to be entirely separated from each other.

The due proportion of the size of the different tubes and flues entering and leaving the heat-box is a matter requiring careful judgment. The inlet for cold air, in its smallest part, ought to have a transverse sectional area of $\frac{1}{6}$ of a square foot for every pound of coal (anthracite) burnt per hour in very cold weather; and the latter may be estimated at $\frac{1}{300}$ of the probable monthly consumption for average weather. (C. B. Richards.) For example, a furnace, burning on an average two tons a month, will burn in the coldest weather $\frac{4480}{300}$ = nearly 15 pounds per hour, which fixes the sectional area of the inlet at $\frac{15}{6} = 2\frac{1}{2}$ square feet = a space 18 × 20 inches square.

A current occasionally flows *downward* in one or another of a set of furnace-ducts. We can sometimes trace the cause of this tendency; the phenomenon is analogous to that of one chimney sucking another, when both connect with one room. It arises from a considerable disproportion in the "ascensional forces" in the tubes. A short tube entering a cold room might easily draw the cold air down into the furnace-box, instead of sending warm air up. The remedy is furnished in part by so proportioning the size of the collective exits to the size of the inlet that cold air entering at the latter expands in proportion to the greater capacity presented by the outlets, and not more. "The collective area of the hot-air pipes should be not more than $\frac{1}{6}$ greater than the least area of the cold-air inlets, assuming that the heated fresh air is to enter the rooms at the temperature of about 120° when at zero outside, and its velocity in the hot-air pipes not exceed 5 feet per second."

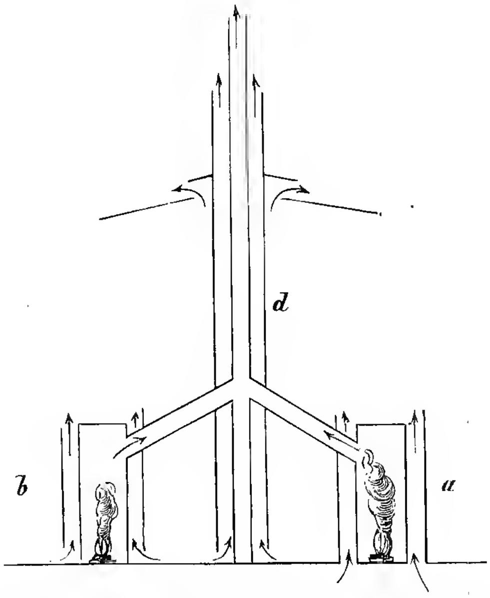

Fig. 16.—Combination of several modes of ventilation for barracks: *a*, stove with mantel, admitting fresh warmed air; *b*, stove with mantel, to promote circulation in the room; *d*, shaft for aspiration of air from level of floor; through the middle ascends the conjoint funnel of *a* and *b*. Ridge-pole ventilation is also seen. (From Roth and Lex.)

A cold-air duct opening on the lee side of a house has a tendency to convey its air in the wrong direction, or the in-draught is lessened. One opening on the windward side requires a valve. In some large buildings with many flues the orifice is so exposed that the difference between the two sides is very troublesome. This may be remedied (as proposed by Mr. Tudor) by providing a receptacle of air of large size and convenient position, into which ducts open from various sides in the walls; the supply is thus made constant.

4. *Ventilating power.*—The air absolutely required for the combustion of fuel is very small, and in the "air-tight" stove, where all superfluous

currents are checked, is practically of no account in ventilating a room. The amount of air used in stoves burning wood is stated at 5 cubic metres for each kilogramme of wood, 7 for coal, and 11 for coke (Bosc; and Degen nearly the same)—that is, 80, 112, and 175 cubic feet per pound respectively.[1] By this it appears that the ventilating power of a close stove is, roughly speaking, equivalent to one-tenth of that required by the needs of a single adult person. Morin estimates the consumption of air by a close stove at 120 cubic feet per pound of coal.

The "open" stove, the so-called "Franklin stove," and the "Fire on the Hearth" are in a totally different category, and discharge nearly as much air as an open fire. The word "Mantelofen" is used in Germany for the class of stoves which possess an outer jacket or casing, into which air is admitted at the bottom, and discharged in a heated state at the top, as shown in diagram in Fig. 16. In stove *a*, fresh air is represented as entering from out-of-doors. In stove *b*, the air of the room enters, and is discharged; the benefit of the arrangement consisting in the wider and more powerful circulation given to the air, and also in the diminution of direct radiation from the surface of the stove. A contrivance like *a* could very easily be applied to most stoves; the jacket should reach the floor, and air should be conveyed into its cavity through a register in the floor. The register should open into a duct placed in the flooring, which should lead to a hole in the house-wall.

Fresh air is also introduced by the hot-air furnace; but, in point of fact, the supply is in most cases quite inadequate.

5. *Economical results.*—The table which follows contains the results of experiments made in 1865–'66 by Morin:

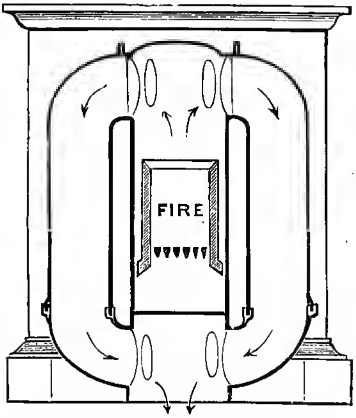

FIG. 17.—Diagram of furnace, with system of tubes for obtaining the heat of the smoke. (Péclet.)

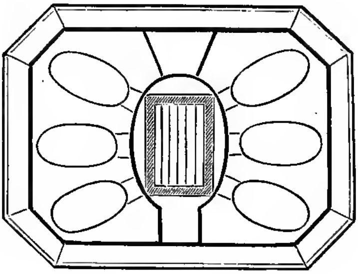

FIG. 18.—The same in horizontal section.

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[1] Parkes' Hygiene states that for complete combustion, one pound of coal demands 240 cubic feet of air; wood, 120 cubic feet.

AMOUNT OF HEAT RENDERED BY VARIOUS APPARATUS.

Name of apparatus.		Percentage of heat utilized.	Remarks.
Ordinary fireplaces		0.10–0.12	They remove bad air, without directly introducing fresh air. The effect on health is good.
Fireplaces with provision for introducing fresh air.		0.33–0.35	They remove bad air, and introduce fresh air moderately warmed. The effect on health is good.
Ordinary stoves without circulation of air.	Cast-iron, heated with Coal	0.90	They remove very little bad air, and therefore are not wholesome.
	Coke	0.83	
	Earthen stoves heated with wood	0.87	
Certain stoves of wrought-iron, with circulation of air, taken from the room or from the outer air.	The school-stoves of Paris	0.68	They remove the bad air incompletely, and raise the air introduced to an excessive temperature. If the tubes for circulation are of cast-iron, the effect on health is very bad.
	Stoves with vertical tubes for circulation (Système Chaussenot)	0.93	
Furnaces with tubes for circulation of smoke.	Horizontal	0.63	They cannot produce a direct and sufficient evacuation of the bad air; in general, they heat the air to excess. The latter objection may be remedied by proper contrivances, so that the air is heated only to 30° or 40° (= 86° and 104° F.). This method is unhealthy, unless connected with a system of ventilation.
	Vertical	0.80	
Heating by warm water.	When the extent of tubing and size of water-stoves is sufficient, in accordance with the demands of theory.	0.65–0.75	Adapted in all cases to the establishment of a system of ventilation by draught-chimneys.
	When the boiler, the fire, and all the stoves or tubes are in the rooms they are designed to warm.	0.85–0.90	

A very great saving in fuel is made by causing the smoke to part with some of its heat in a system of tubes. In Fig. 17 an arrangement of this sort is shown in vertical section; the smoke passes from the top of the fire, by six flues, to the floor of the air-chamber, where it is gathered in one flue and discharged downward. Fig. 18 gives a horizontal section.

In Fig. 19 the great mass of smoke and gases of combustion enters a large chamber, which connects with several tubes, each, however, returning to the same chamber after a downward circuit. The circulation in these tubes takes place in obedience to the principles which govern a system of hot-water heating-tubes. Their contents become cooled in the brick chamber, and descend, to re-enter the smoke-box; while the place of the cooled gases is supplied by warmer gas. The discharge of smoke to the chimney is independent of this circulation.

A simpler means of saving heat consists in letting the smoke-flues run exposed to the air, as is very commonly seen in cheap buildings. A far better plan is to convert the fireplace into a species of Galton's stove. For this purpose a tight, flat chamber of masonry, of no great depth, and a few feet wide, in the space behind the mantel, is to be provided.

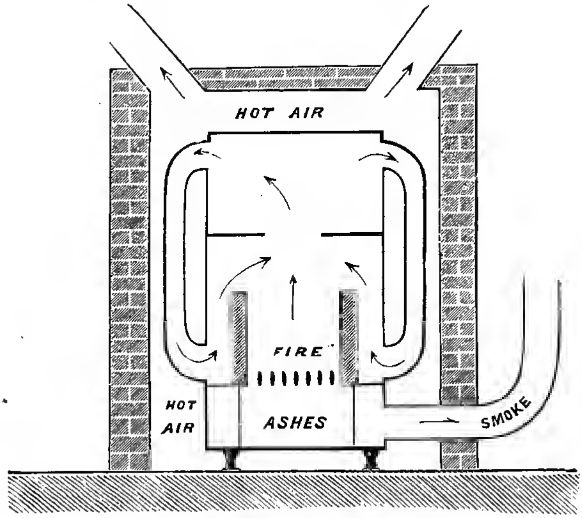

Fig. 19.—Furnace, with circulation of smoke.

The smoke-flue from the stove (an open-grate stove of ordinary pattern) passes up and down in this space, making several (say four) bends, and exposing a great length to the air of the chamber, which then enters the room by a register. Fresh air is supplied to the chamber by a flue communicating directly with out-of-doors.

Heating by Steam.

This method is becoming very popular in America, even for dwelling-houses, while for public buildings it possesses certain distinct advantages.

A steam-apparatus is compact and easy to manage. It can be put in operation quickly. It transfers heat to any desired distance in a horizontal direction; whereas air from a furnace cannot be distributed over a radius of more than forty feet. It is easily managed by any fairly intelligent domestic.

On the other hand, the noises made by the steam entering the pipes in the morning, after the apparatus has grown cool, are very annoying. So are leaks, which may be hard to find and repair. Explosions are known to have occurred. Yet these objections can be answered to a great extent. The noises in the pipes are due to local accumulations of cool water, causing sudden condensations of the hot steam when they first come in contact;

and this can be avoided, to some extent, by careful grading of the pipes, so that a constant descent shall exist from the highest part of the system to the lowest, permitting all condensed steam to flow back into the boiler. The latter should be placed at a lower level than the lowest pipe. There are also various arrangements (steam-traps) for automatically evacuating the water and air at given points. When it is not practicable to return it directly to the boiler, automatic air-traps release the air which accumulates in heaters. As regards explosions, they should not be permitted to become possible. One of the leading manufacturers of steam-apparatus in Boston is accustomed to require an inspector's certificate of a test of 150 pounds to the square inch for boilers which, in ordinary use, are not to be subjected to a pressure of more than 5 or 10 pounds. This is "low-pressure;" while 15 or 12 pounds may be called a medium. The advantage in using a higher tension than that of 5–10 pounds depends on the fact that steam produced under such conditions has a higher temperature, and that a considerably less amount of pipe will suffice to produce a given result. The temperature of pipes at medium pressure is, roughly speaking, from 250° to 260° F.; at ordinary low pressure [5 lbs.], 228°.

In laying pipe to connect the boiler with the "coils" or heaters, it is necessary to protect against waste of heat by a casing of fibrous material. Various substances are manufactured for this purpose, the best of which are founded on the use of asbestos. In passing through wood-work (floors, etc.), the pipe must be guarded by packing for protection against fire.

If precautions of this kind are used, gutters containing pipe may be laid in the floor.

A coil of steam-pipe is often placed in a chest of water, forming what

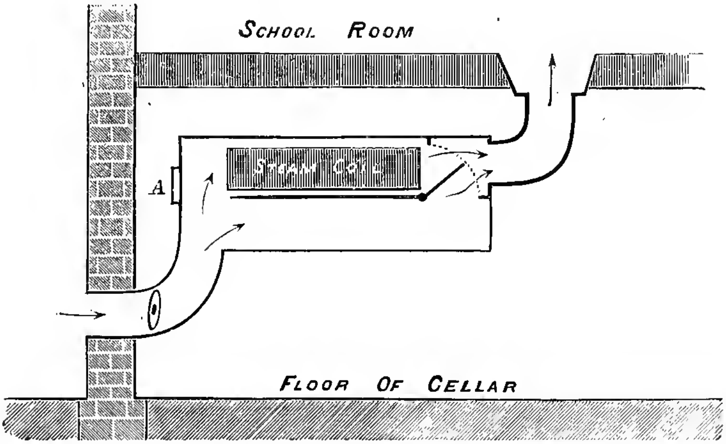

Fig. 20.—Steam-coil in cellar: valves to control source of supply of air, and its course within the heater.

is called a "water-stove." The apparatus heats rather slowly, which may be thought a disadvantage; but, on the other hand, it retains heat for a long time, and, as its top is open, the temperature never exceeds 212° F., while the fresh air within the mantel does not exceed 45°.

The ordinary application of steam to heating purposes consists in placing coils in the rooms to be heated, without provision for the entrance of fresh air. This is extremely objectionable. Many modern dwellings, especially in "family hotels," are, in addition, so deprived of natural ventilation by the tightness of the joinery, the close fit of the sashes, and the paint and varnish of the walls, as to be extremely uncomfortable. The proper arrangement would be to enclose each coil in a box, forming an arrangement like the system of stove-flues, described at the end of the last section; each box has an inlet for fresh air, and an outlet or register to discharge it into the room. Such a box can be arranged under the window-seat without occupying much space. The same principle can be applied to boxes placed in the cellar of a large building, of which a sketch is given in Fig. 20. A valve at the right hand end of the box directs the flow of the air over the coil, or away from the coil through an empty section of the box, or, in different proportions, partly through each; this gives the power of controlling the temperature of the air admitted to the room, while it leaves the amount constant. The inlet from the outer air has a valve, which can be closed at night, or at other times when the building is unoccupied; another valve, at A, can be opened at the same time to supply cellar air. In distributing the air from such a heater, pipes and registers are used, as in the case of furnace-air. This method is very satisfactory. It has a great advantage in one respect over the hot-air furnace system: the amount of heat given by each box of equal size is exactly equal, in whatever part of the house it be placed.

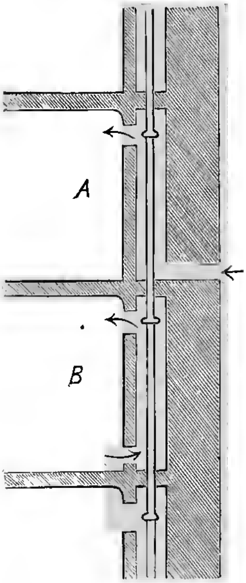

Fig. 21.

No introduction of fresh air, however, can take place unless there be an outlet for its escape from the room; and, as things go, it is not safe to take it for granted that any "ventilating-flues" are in working order, except that surest of ventilators, the chimney, and open fireplace. In a general way it must be said that no room is fit for habitation unless it has a chimney. Exceptions might be noted; but they would readily occur to any observing person.

The annexed figure (Fig. 21) gives a formula for correct and incorrect warming by pipes of steam or hot water. In A the air circulating around the pipe is seen to come from out of doors; in B it is drawn from the room to which it is returned.

Heating by Water.

This may be placed by the side of steam-heating. It gives a less intense heat than the latter, and is not liable to certain objections. Its recommendation is its great equability and mildness; as the temperature of the air in contact with water-pipes does not usually rise above 45° C. or 113° F. Its drawbacks are the slowness with which an apparatus is usually heated when once cooled down, and its comparative expensiveness in daily use.

The principle which governs the circulation in a system of hot-water pipes is based on the laws of gravitation. A circle of pipe, entering a boiler or a furnace at one side, is more heated at that side, and the water in that part rises, while the water in the other parts, being cooler, passes in to fill its place. The principle is quite the same, whether a simple circle is used, or whether at various points the pipe enters a "coil" or a tank of whatever shape for the rapid distribution of heat. Nor is the case affected by the use of a boiler in some systems, and of a series of pipes in contact with the fire in others. It is essential that a point should be left open to the air at the high level, to give room for the expansion of the water. This point may be, and usually is, at a tank.

The surface of tube required is greater than in the case of steam-heaters, from one-half to one-fourth, which constitutes an economic objection to the use of water.

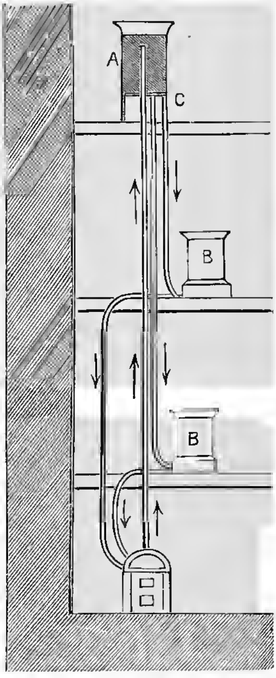

Fig. 22.—Diagram of a system of heating by hot water.

The opinion of Dr. Billings, derived from a comparison of the results of a steam-heat system in the Boston City Hospital with the hot-water system in the Barnes Hospital, is in favor of the latter. He expresses "a preference for the use of hot-water apparatus with large heating surfaces of a comparatively low temperature, *i. e.*, from 100° to 160° F. My objections to steam-heating, as I had seen it, were that the air is generally overheated, that the various valves and other contrivances for mixing cold air with the superheated air in order to produce the proper temperature are generally unsatisfactory; the air escaping in alternate puffs of cold and hot air; that, unless very carefully set, there is liability to annoyance from noises in the pipes due to condensation; and that more constant and skilled practical supervision is necessary with the apparatus. From practical trial with the hot-water method, I am perfectly sure that for heating purposes it is entirely satisfactory, and is probably cheaper than steam.

"From information furnished by Dr. Cowles, and from my own observations, I believe that the method used in the new wards of the Boston City Hospital (steam) gives satisfactory results; results, so far as temperature and ventilation are concerned, as good as, but no better than, the hot-water system."

In some of the other buildings (other than wards) he thinks that steam would probably be less expensive than hot water.

A combination of steam and water heating may be made, which will avoid some of the objections of each.

Such a system, as seen by the writer, consisted of a cylindrical stove, lined with fire-brick, and with nothing peculiar in its construction, except that iron pipes containing water encircle the fire-pot within, in contact with the fire. These pipes are continuous with a set which makes the circuit of a room or rooms on the level of the stove. At a high point in this circulation, a pipe leads to a second set of tubes containing no water, which are led to higher levels or upper stories. Steam in moderate amount, and at the pressure of the atmosphere, is constantly passing from the water circuit up into the steam circuit; and free escape is allowed for any surplus steam at a distant point. The danger of explosion seems to be entirely obviated by this plan, and, as far as tested, its economic value is considerable.

VENTILATION.

The amount of fresh air required by an adult may be estimated by reference to the amount of carbonic acid given out, and the amount of air required to dilute this to a degree arbitrarily assumed as a normal standard of purity for houses.

An adult man (Parkes), in ordinary work, gives off in twenty-four hours from 12 to 16 cubic feet or more, according to weight, of carbonic-acid gas, and also emits an undetermined quantity of carbonic-acid gas by the skin. On an average, an adult man, not doing excessive work, may be considered to give to the atmosphere every hour not less than 0.6 cubic feet of carbonic acid. Pettenkofer states the amount at about 0.7.[1] Women give off less, and children and old people also give off a smaller amount.

The following observations give the amounts of CO_2 excreted by different persons and classes:

I. PETTENKOFER AND VOIT.[2]—DISCHARGE PER HOUR.

	I. Strong laborer, weight 72 kilogr., age 28.		II. Weak tailor, weight 53 kilogr., age 26.
	At rest.	At work.	At rest.
By day	22.6 litres	36.3	16.8
By night	16.7 "	15.	12.7

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[1] This is the quantity adopted by Roth and Lex (Militär-Gesundheitspflege).

[2] Zeitschrift für Biologie, Bd. II., p. 546.

II. SCHARLING.[1]

	Age.	Weight.	Hourly discharge of CO_2.
Boy	9¾	22 kilogr.	10.3 litres.
Girl	10	23 "	9.7 "
Youth	16	57.75 "	17.4 "
Young woman	17	55.75 "	12.9 "
Man	28	82. "	18.6 "
Woman	35	65.50 "	17.0 "

III. BREITING[2] (FROM ANALYSIS OF AIR OF ROOM FOR CO_2).

SEX.	Age.	Amount CO_2.	Time.
Girls	7–8	10.7	Regular hours of instruction.
"	7–8	10.5	
"	8–9	12.0	
"	8–9	16.7	Hours of singing.
Boys	12–13	13.1	Regular hours of instruction.
"	12–13	13.0	
"	12–13	17.	Singing.

The hourly supply of air required by each person may be estimated as follows: The amount of carbonic acid excreted by the lungs is assumed as = 0.532 m. in 24 hours, which corresponds to 12.2 m. of expired air containing 4.334 per cent. (Vierordt) of carbonic acid. Now, if this expired air be added to 99 times its volume of atmospheric air, containing the usual proportion of 4 per ten thousand of carbonic acid, it is evident that (disregarding minute fractions) the amount of CO_2 in the air is simply doubled; it is raised to 8 per ten thousand. And if to this mixture be added its own volume, again, of atmospheric air, we have a second mixture containing the mean of 4 and 8, or 6, parts in ten thousand, which is an allowable amount, and for most purposes may be considered all that is attainable. One hundred and ninety-nine (say two hundred) times the total bulk of the expired air is therefore required to dilute it to a proper degree. This equals 2,440 m. daily, or about 100 m. per hour—that is, in round numbers, 3,500 cubic feet. This is necessary in rooms which are constantly occupied; and in rooms for assembly, or schools, where such a liberal ventilation is impossible, the greatest care should be taken to give a thorough sluicing-out with fresh air at short intervals; at least after each session. In legislative halls the sessions are so protracted that the requisition for air may approach that in a hos-

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[1] C. G. Lehmann: Handbuch d. physiol. Chemie, Leipzig, 1854.

[2] Band III., p. 320.

pital, which, as given by De Chaumont, equals about 3,000 cubic feet per hour, but, as stated by Billings, is one cubic foot per second per man as the minimum allowance, or 3,600 feet per hour, which is over 100 cubic metres.

The quantity of fresh air required per hour and head, in order to keep the air of a room at a given standard of purity, may be calculated by a simple formula:[1]

$$y = \frac{k}{p-q};$$

in which

y = volume of air required.

k = volume of CO_2 produced by the persons, lights, etc.

p = proportion of CO_2 to be allowed (.0007, Pettenkofer) to each volume of air.

q = proportion of CO_2 existent in each volume of normal air (if quite pure, in cities = .00037).

In this equation, the reader need not be told that p and q vary considerably in different authors and places.

If, for example, a school-room contains fifty pupils of the age of nine or ten years, we may assume, in round numbers—

$k = 10 \times 50 = 500$ litres = 0.5 cubic metres.

$p = .0007.$

$q = .00035.$

$$y = \frac{0.5}{.0007-.00035} = 1428 \text{ cubic metres.}$$

But if we assume a higher standard of purity and place, as we may,

$$p = .0006,$$

while the air-supply is assumed as of only the average town quality, say

$$q = .0004,$$

the equation reads:

$$y = \frac{0.5}{.0006 - .0004} = 2500 \text{ cubic metres,}$$

or about 1,750 cubic feet per scholar, which is quite a moderate estimate.

The estimate is, in fact, too moderate. Instead of 10, let us allow 15 litres carbonic acid as expired hourly by each pupil in a school, or adult in a room; this raises the value of y by one-half, or from 1,750 to 2,625 feet per hour.

If we assume 20 litres as the normal production (for adults) per hour, as is done by Herter, we double the value of y, making it 3,500 cubic feet, or 100 cubic metres per hour and head.

"It is impossible to keep the air in rooms of a purity equal to that of the outer air; the amount to be introduced would have for this purpose to be infinite. But we may be sure, from calculation and experiment, that a ventilation to the extent of 100 cubic metres per head and hour will give a perfectly good, wholesome air, always supposing that the mix-

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[1] Schultze und Märcker: Handbuch der Militär-Gesundheitspflege, Bd. I., p. 221.

ture of air takes place quickly and uniformly, and that the only source of impurity is that derived from the human exhalations."[1]

Morin's table of the amount of fresh air required per hour and head, though well known, may be given here. It presents, for certain cases, far too low an estimate. The amount of CO_2 eliminated from the lungs of children is not so much smaller than that from adults as to make it safe to reckon less cubic space for the former.

	AIR PER HOUR AND HEAD.	
	Cub. metres.	Cub. feet.
Hospitals for ordinary patients	60–70	2119–2472
" " wounded and lying-in	100	3532
" " epidemics	150	5298
Prisons	50	1766
Ordinary workshops	60	2119
Workshops with special sources of contamination of air	100	3532
Barracks, by day	30	1059
" by night	40–50	1413–1766
Theatres	40–50	1413–1766
Public assembly-rooms—		
For long use	60	2119
For short use	30	1059
Schools for adults	25–30	883–1059
" " children	12–15	424–530

The following estimates of the amount of carbonic acid produced by different illuminating materials may be of use.

R. A. Smith (Air and Rain, p. 110) gives a calculation of the amount produced by two men, working with two candles, as is usual in mines, during a period of eight hours. The two men will produce 10.4 cubic feet of CO_2, and the two candles 12.2765 feet, at a temperature of 70° F. This gives the production of a mining-candle, relatively to that of a man, as nearly equal 7 : 6; a candle produces $1\frac{1}{6}$ times as much as a man.

In another place he says: "I afterward found in some experiments (with the lead chamber) that the man gave, as nearly as possible, double the amount of carbonic acid given by a sperm or paraffin candle. A man produced in an hour .6 of that gas to 100 feet of air; a candle, .31. The miners' candles produced more, as is believed; but this was not estimated."

The following table is given by Lunge from Erismann for several kinds of lights:

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[1] Herter: Vierteljahrschr. f. gerichtl. Med., 1874.

Form of illumination.	Consumption per Hour in		Amount of light meas. by candles.	Production of CO_2 per hour. (In litres.)
	Grammes.	Litres.		
Petroleum, slit-burner	35.5	0.045	10.0	56.8
“ round-burner	50.5	0.064	7.6	61.6
Oil-lamp	22.4	0.025	*ca.* 4.0	31.2
Candle	20.7	......	1.0	11.3
Coal-gas, slit-burner	....	140.	7.8	92.8
“ flat-burner	....	127.	10.0	86.0

The figures in the last column may be compared with those for the human production of CO_2 by dividing by 20.

It is stated by Roth and Lex that the quantity of carbonic acid produced by flames giving equal light is, in the case of

Street-gas.......................... 155 litres per hour.
Rapeseed oil .... 87 “ “
Petroleum.......................... 75 “ “

Wolpert found, disregarding the quantity of light, that the carbonic acid produced by

Street-gas, with simple burner = 40 litres.
“ “ batswing “ = 240 “
One stearine candle......... = 12 “

Which corresponds roughly to the amounts produced by 2, 12, and ½ person respectively.

The quantity of CO_2 produced by street-gas in burning may be calculated from chemical data.

The burning of illuminating-gas produces (Lunge) 681 parts of carbonic acid to 1,000 parts of gas. A burner giving a light equivalent to 7.8 normal candles, using 140 litres of gas per hour (about 5 cubic feet), produces in an hour 92.8 litres of carbonic acid. If we allow for the total daily excretion of CO_2 by a single average man, the amount of 406 litres, or 800 grammes,[1] we find that the burner produces as much carbonic acid in a given time as five and four-tenths average men. This is, perhaps, a little too high.

It is a question, which has received considerable discussion, whether a sleeping-room ought to be ventilated as freely as a day-room. The answer embraces several points. For civilized men, in cities, enjoying only limited opportunities of inhaling fresh air, the question must be answered in the affirmative, with some slight allowance for the diminished excretion which occurs during sleep. In the language of Pettenkofer: “He who will sleep healthily in a cold room, must not only have a good bed,

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[1] Pettenkofer and Voit. It varies, however, from 686 to 1,285 grammes.

but also a large cubic space, or very poorly fitting doors and windows, or very porous walls, or else he must leave a window partly open, in winter as well as in summer."

The good health, however, apparently enjoyed by men who labor out of doors and sleep in close rooms, is an argument in favor of the view that the blood and tissues, if largely supplied with oxygen by day, do not require nearly as much by night. It is also the habit of wild animals to seek close places to sleep in, for security, no doubt, in the first place. The habits of hibernation in certain animals prove that the excretion of carbonic acid goes on at a very much lessened rate under certain circumstances; and they seem to require almost no "cubic space" to breathe in during that period of retirement. The habits of a hardy and exposed life greatly strengthen the powers of resistance to narcotic influences; the mountaineer's capacity for imbibing whiskey, and the unlimited indulgence in tobacco which the traveller can enjoy during a sea-voyage, both illustrate this fact, and perhaps the tolerance of a bad air by night is a parallel fact.

In any case, it must be regarded as conducive to health to breathe absolutely fresh and pure air at all times. The habit of sleeping in the open air may be acquired and enjoyed by well people in any temperate season and climate; its effects, when once tolerated, are unquestionably in the direction of improved health. The results, in the briefest terms, of a temperate life in the open air in a good climate, are that one is never sick or ailing; that diseases contracted are thrown off easily; that wounds heal quickly. Vigor acquired by exposure in the daytime need not be wasted by carbonic-acid narcotism during the hours of sleep; it is *as safe* to sleep in a wholesome air as it is to be awake in it.

In illustration of the value of a thorough system of ventilation as applied to a hospital ward, the following statements are extracted from an article in the Report of the Massachusetts Board of Health for 1879, by Edward Cowles, M.D., Superintendent of the Boston City Hospital:

"In June, 1876, two new surgical pavilions were opened at the Boston City Hospital, and important changes in the sanitary arrangements of the old buildings were begun. Previous to this time there had been several endemics of pyæmia and other septicæmic affections, which had very seriously increased the fatality, as well as retarded the recovery of the patients. In no class of cases was this pernicious influence more conspicuous than in compound fractures of the extremities. During the five years ending June 1, 1874, the mortality in these injuries (157 cases) was forty-one per cent., while in the two and one-half years following the introduction of improved sanitary conditions, the death-rate (in fifty-one cases) was not quite twenty per cent.—a reduction in the mortality of more than one-half."

In cases treated without amputation, "the percentage of recoveries has increased from fifty-six to eighty-seven, or more than fifty per cent.; the mortality has fallen from forty-four per cent. to thirteen per cent."

"Amputations have been less frequent, and the results have been more favorable than formerly. The frequency of and fatality from pyæmia has decreased one-half, and all the affections depending upon blood-poisoning have been greatly diminished in the past two or three years." No new or improved method of treatment seems to have had any influence in producing these results.

The hourly supply of air is the chief factor in determining the size of a room. Into a small room we can introduce only a proportionably small amount of air in a given time. This limitation rests on the fact stated by De Chaumont, by Roth and Lex, that when the air in a room is changed more rapidly than three times in an hour, unpleasant draughts are felt by the inmates. If, then, we assume that each adult occupant of a room requires 100 cubic metres of fresh air hourly, or 3,500 cubic feet, we must allow nearly 1,200 cubic feet of space per head, which is a great deal more than is usual. This requirement, however, is hardly excessive in the case of a hospital, where "1,000 cubic feet should be the minimum allowance to each person" (Billings); it ought, in fact, to be exceeded.

The cubic space allowed by the regulations of the British army to soldiers in barracks is—

In permanent barracks	600	cubic feet.
In wooden huts	400	"
In hospital-wards at home	1,200	"
" " in the tropics	1,500	"
In wooden hospitals at home	600	"

The sensible qualities of the air in a room ought to be considered as important. A bad smell—an odor of dirty linen, of musty books, of excreta, or perspiration, or stale food—must not be perceived. The "hospital smell" must, as far as possible, be got rid of by diligent scrubbing and cleanliness, minute in details.

The best test of good air (not to exclude the sense of smell, which is subject to the influence of a varying personal equation) is obtained by examining for the presence of carbonic acid at various levels in a room. It is desirable to ascertain, by the use of the anemometer, the amount of air entering a room or leaving it; but the chemical test supplies a most valuable piece of information, relating to the diffusion of the introduced fresh air in the different parts of a room.

In Lang and Wolffhügel[1] are to be found formulæ, by Seidel, Hagenbach, and Kohlrausch, for calculating the amount of ventilation from the variations in the amount of CO_2 in the air.

Methods.

Ventilation is either natural or artificial.

Natural ventilation is a term of somewhat loose application. We shall consider it as limited to the supply of air which enters through pas-

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[1] Ueber Lüftung und Heizung von Eisenbahnwagen.

sages not intended for the purpose—cracks and pores in the walls, doors, and windows. It is necessary to consider the chimney as an ally in natural ventilation. The rate at which air is extracted by a chimney depends on its height and the difference between its interior temperature and that of the outer air.

It may be remarked by any person of observation that houses exposed to the wind are apt to have a fairly good air within, even in the lack of a system of ventilation. This is a perfect illustration of what is meant by "natural" ventilation. Air enters such a house at all the cracks on the windward side, and leaves it on the leeward and by the way of the chimney. But a more important element in natural ventilation (according to Pettenkofer) consists in the porosity of the walls, through which enormous quantities of air pass unsuspected.

In order to determine the extent to which "natural" ventilation affects the air of a dwelling-room, Pettenkofer applied the reaction for carbonic acid. He found that in a room with brick walls, containing 75 cubic metres of air, or about 2,700 cubic feet, the air contained was completely changed once in an hour when the temperature outside stood at 32.2° F. and inside at 64.4° F.—a difference of 34.2°. At the same temperatures, a brisk fire being made in the stove, and all the valves and doors opened to the chimney, the hourly change amounted to 94 cubic metres, or nearly 25 per cent. increase. But when all the cracks in the doors and windows, and even the keyholes, were closed with strong paper and paste, the change of air still equalled 54 cubic metres in an hour, which is only 28 per cent. less than the first result. This effect was very much dependent on the difference of temperature between the outer and the inner air, as is shown by the fact that when these equalled respectively 64.4° and 71.6° F., the average change of air was only 22 cubic metres per hour; and even the opening of a window, with a space of 8 square feet, increased the change of air only to 42 cubic metres per hour.

It is a familiar fact, though not sufficiently heeded, that it is harder to ventilate a large school-house than a small one. It is perfectly evident that a small house exposes a much larger surface of wall, proportionately to its size and the number of pupils, than a large house, and hence the natural ventilation is much more vigorous. The difficulty of overseeing an extensive and complex apparatus is another source of imperfect ventilation in large houses.

The direction and force of the wind also greatly affect the natural ventilation. A chimney draws less actively when its fireplace is turned away from the direction the wind comes from; and a room which with one wind may receive a great deal of out-door air through crevices, with another wind may lose as much of its own air, in the outward direction, the place of that lost being filled by air from the other parts of the house.

The quantity of air passing through a porous building-material is directly proportional to its constant of permeability and to the difference in atmospheric pressure upon the two sides; it is inversely proportional to the thickness of the wall. The difference in the permeability of materials is shown in the following table, taken from Lang :

Material.	Constant of permeability.
1. Calcareous tufa	7.980
2. Slag-stone, from Haardt a. Sieg, 1873	7.597
3. Slag f. Zuffenhausen	5.514
4. Slag, English	2.633
5. Slag from Osnabrück, 1873	1.890
6. “ “ 1871	1.720
7. Cendrin-stone	1.327
8. Pinewood over Hirn (Querschnitt)	1.010
9. Mortar	0.907
10. Brick (Ziegel), pale, Osnabrück	0.383
11. Beton	0.258
11. Handziegel, hard-burnt, Munich	0.203
13. Clinker, unglazed	0.145
14. Portland cement	0.137
15. Machine bricks (Ziegel), Munich	0.132
16. Green sandstone, Upper Bavaria	0.130
17. “ “ Switzerland	0.118
18. Handziegel, soft burnt, Munich	0.087
19. Oakwood over H	0.007
20. Gypsum, cast	0.041
21. Clinker, glazed, impermeable	0.000

Painting has a very great effect upon the permeability of walls. A first coat of oil-paint lowered it, in the case of mortar, from 100 to 90.6; sandstone and brick and clinker to 66.6; a second coat reduced gypsum to 0, mortar to 19.6, and the others to 3.5 and 5.2.

“Coating with water-glass[1] probably in time completely destroys the permeability of a wall ; so does oil-paint, while new, although the cracks which come in the course of time make a considerable difference. When I state that oil-paint is the principal agent in preventing the diffusion and passage through the walls of the watery vapors which originate in domestic processes and respiration, it will be necessary for the science of hygiene to decide whether *water-glass and oil-paint will have to be condemned.* Size-colors also lessen the permeability considerably, and in proportion to the strength of the size ; that used by me was so feebly sized that it lost color, and yet the amount of air passing through was lessened by one-half ; the smallest loss of permeability occurred when lime-colors were used.”

Papering a wall has a similar effect, though to a less extent; in the case of various stones and brick it was lowered from 8.5 per cent. to 46.8 per cent.

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[1] Lang: Loc. cit., p. 88.

Moisture has a great effect in arresting the passage of air; this occurs in inverse proportion to the porosity of the material. Restitution also takes places in proportion to the porosity.

Window Ventilation.

Great economy of fuel could be attained by introducing double windows. A single thickness of glass cools the air enormously; and, if one is sitting under it, a draught of falling cold air is felt which is both real and dangerous. This draught is not due to the entrance of cold fresh air, but is produced by the chilling of a layer of warm air in contact with the glass, which naturally falls to the level of the floor. Another use of double windows is that of direct ventilation. Let the lower sash *outside* be slightly raised, and the upper sash *inside* slightly lowered; air will then pass between the two sashes, and will enter the room near the ceiling, having in its passage over six feet of glass (inner window) received a good deal of heat from the room, and being therefore partially warmed before entering.

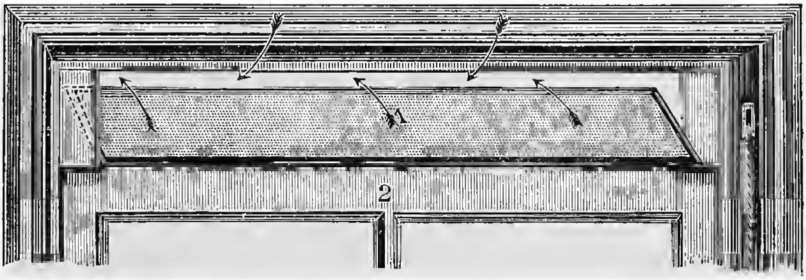

FIG. 23.

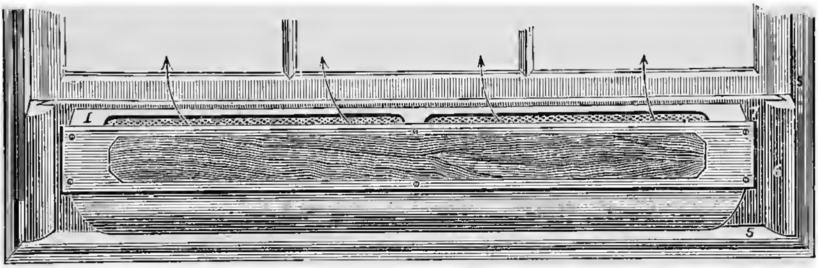

FIG. 24.

One of the simplest remedies for bad air is to fit a board, of the breadth of three or four inches only, under the lower sash (of a single window); this shuts out no appreciable amount of light, and raises the sash so that, between its upper part and the lower part of the upper sash, a current of air is admitted in an ascending direction. This plan is extremely cheap, and may be used anywhere; it is quite effective in cold weather.

Another plan consists in placing a narrow board at the top of the upper sash, tilting a little inward, so as to let the air pass over it and strike the ceiling.

A neat and useful modification of this plan is seen in the cuts given on the preceding page (Figs. 23 and 24).

The purpose of this contrivance is to admit fresh air into the room in a current of such diminished velocity that no draught will be felt. This is attained by lifting the lower sash a few inches, and placing beneath it a double fibrous screen, which fits the window-frame tightly (Figs. 24 and 25). The sash may be raised and lowered independently of the ventilator.

These screens serve a double purpose; they retard the current of inflowing air, and at the same time deprive it, by filtration, of its coarser impurities.

To give exit to foul air, the upper sash is lowered a few inches, and a hinged screen is fitted into the space between the window-frame and the sash. If the wind out-of-doors is blowing toward that side of the room, the screen folds up automatically and excludes all unfiltered air. If the wind, however, blows from the opposite direction, the screen falls outward, and allows the heated and foul air of the upper portion of the room to escape unhindered.

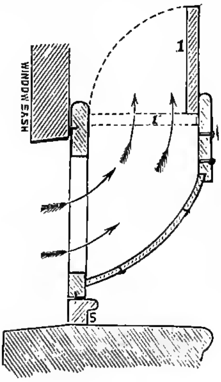

Fig. 25.

Perforations in window-panes are often of service. One plan is, to insert in the place of one pane several horizontal bars of glass, the slits between which are slanted so as to throw the air upward. Another plan is to insert a circular whirligig of metal; this is often seen in rapid motion, forcing air in, but often is idle, and is easily broken or put out of order.

Wind-sails are a kind of cowl and pipe made of canvas, and used on shipboard to ventilate lower decks. They may be profitably imitated on land. A tail like that of a windvane makes the orifice point in the proper direction for catching wind and passing it down the tube into the house. There is also a revolving apparatus, which throws a current of air down.

Artificial Ventilation.

The systems of artificial ventilation are chiefly classified under two heads: those which force the air into a room (pulsion: plenum system), and those which draw the air out (aspiration: vacuum system). Both have their points of value, and they may be advantageously combined.

The most familiar instance of *aspiration* is furnished by the ordinary chimney. In summer the action of the chimney may be increased by placing in it a lamp, or, better, a gas-jet or two. According to Morin, 7 cubic feet of gas, burnt per hour in a flue 11 inches square and 66 feet high, draw 13,300 cubic feet of air per hour from the room. The effect is not proportional to the amount burnt, for 50 feet of gas burnt in the same time will evacuate only 22,500 cubic feet of air. The statement of

Degen, that 1 cubic metre of gas will evacuate 600–800 metres of air, must not be taken without qualification.

A very useful method of ventilating rooms is furnished by tubes or flues, which may be of tin or zinc, running up in the walls of dwellings, with gas-jets in them, and opening with proper protection above the roof. Such flues may be introduced into old houses (as when such houses are converted into schools) as supplements to the power of chimneys, which are rarely adequate to the task of ventilating such schools.

The annexed figure (Fig. 26) gives a sectional view of a chimney which serves to ventilate a hospital at Glasgow. The mass of masonry is pierced with flues for the different fireplaces, which are in part represented. It is seen that an opening is made in the upper part of the wall of each room over the fireplace, through which air escapes into the chimney-flue. In Fig. 27 two rooms are seen, provided with channels for extracting air (as above) through the fireplace and the opening over it, and with inlets for air by the ceiling, and over and under the sashes in various ways.

Ventilation by pulsion, as well as by extraction, requires a system of ducts or flues for the air, and the rules for the size and proportions of such ducts are similar in either case.

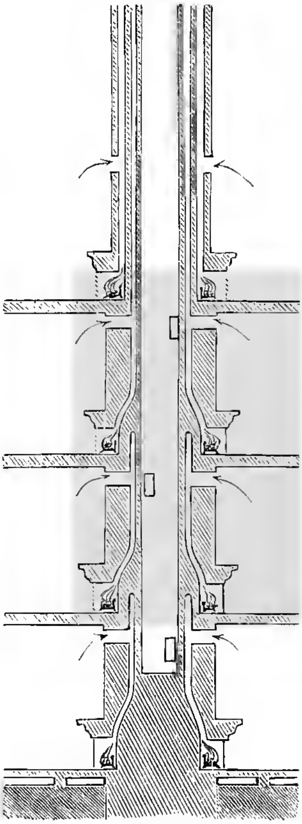
FIG. 26.

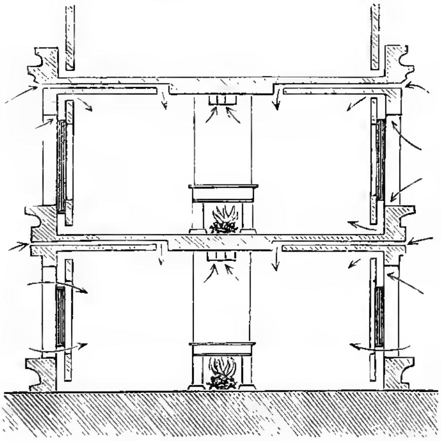
FIG. 27.

The primary ducts, or those connecting with the room, are smaller, and therefore a lower velocity of the air in them is suitable. The union of several ducts forms a larger one (secondary duct), in which the air may move more rapidly without needless waste of force by friction. In the draught-chimney, to which all converge, the rate may be greater still. These velocities, beginning with that of a foot and a half or two feet, at the openings from the rooms, are graduated up to seven feet per second (say 2 metres) in the draught-chimney.

The size of the flues and chimney is naturally dependent upon the amount of air to be drawn through them and the velocity. If we wish to extract ten feet per second from a room, and have allowed a velocity of two feet per second at the registers, we require five registers, each a foot square.

The size of a chimney for extracting air from rooms is governed by the amount of air to be extracted. The capacity for discharge depends on several factors: first, the volume discharged is proportionate to the transverse section of the chimney; second, it is proportionate to the square root of the height of the column of air contained; and, third, it is nearly proportionate to the square root of the difference between the temperature inside of the chimney and that of the outer air.

A difference of 20°–30° C., or 36°–54° F., between the chimney and the open air, is required in order to secure abundant and constant ventilation. In summer, therefore, the chimney requires to be heated to a higher point than in winter, in order to give an equal effect; or, in other words, without special arrangements, the draught will become slack in summer. The flue of a cooking-stove, or some other heating-apparatus, may be used temporarily to increase draught. A permanent source of heat, by summer and winter, must also be furnished, in order to secure a degree of uniformity in results. There will be days when a chimney not specially warmed will draw well; but on many days its draught will be very poor indeed. In large buildings the flue of a furnace may be so used as to heat the draught-chimney, and this may suffice; but sometimes a special source of heat is required—either a stove or coils of steam- or hot-water pipe. The heating by pipes, however, is quite expensive.

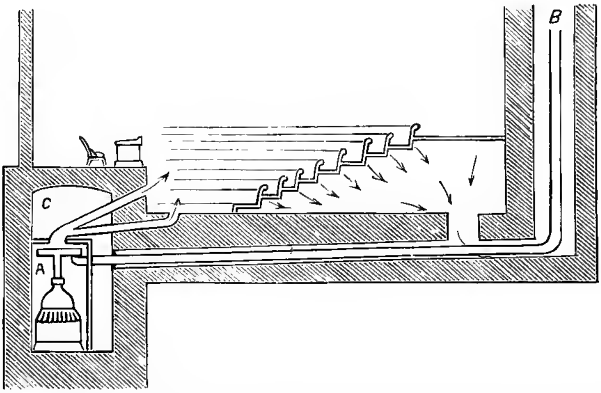

FIG. 28.—Diagram of system of ventilation by extraction: C, cellar; A, hot-air chamber containing a furnace, from which the air is led by pipes in the usual way. From the chamber the air is seen passing horizontally till it reaches the exhaust-shaft, B, where it rises to a considerable height. Openings under the seats lead the foul air to a point which communicates with the shaft. (From Bosc.)

Fig. 28 gives an illustration of this method in a very simple form. Another application, still simpler, is seen in Fig 16.

It will be understood that extraction can be accomplished by mechanical means as readily as by heat, and the same chimney or shaft may be used for discharge, if necessary.

In Figs. 29–32 is represented a system of ventilation said to be very successful. It appears to me inadequate in one point, but is interesting. The first of the figures gives a view of the arrangement in summer. Cold air is admitted by the passage marked *A*, and rises without contact with the heaters, through the valve at *C*, into the lower part of the room. Becoming warmer by contact with the bodies of the pupils, its natural tendency is to rise. It leaves the room at *S*, and is drawn down to *K*, and through the valve there represented, by the suctional force of a chimney.

In spring and autumn, when the temperature of a room containing people is higher than that of the outer air, the arrangement is as in Fig. 30. The cool air passes, from *A* through *H*, into the room, and sinks; the warm air of the room rises through the opening, *S*, into the shaft, where it passes through *D* into an attic story, whence it is discharged into the outer air. It is, perhaps, questionable whether the draught produced by the natural difference of temperature is adequate to the task exacted of it. A more active circulation is produced by letting the air enter at *C* instead of *H*.

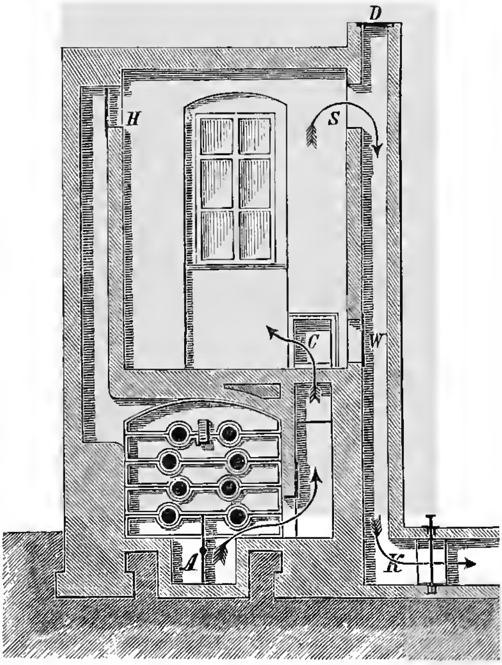

FIG. 29.—Ventilation of the Annen-Realschule in Dresden (summer).

In Fig. 31 the winter system is given. The heated air enters the room at the top, *H*, and leaves at *C*, after parting with some of its heat. The ejection of the air is effected by simply letting it rise through *D* by virtue of its levity. The principle is perfectly correct, provided the air outside is enough colder than that inside; but that being a very variable factor, the force of the draught must vary also with the weather. The arguments for the necessity of an artificial heating of the draught-chimney are given elsewhere.

In Fig. 32 the school is dismissed and the room closed. The fire may

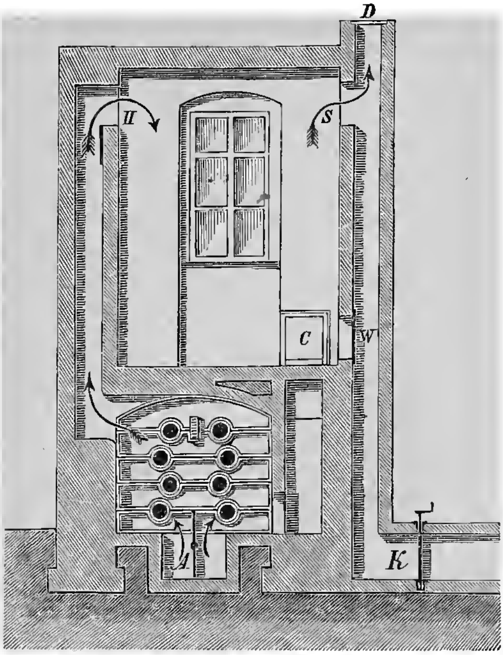

FIG. 30.—Spring and autumn ventilation.

be slackened or let go out; the circulation goes on in the room without removal of air. Moderately warmed air enters from the furnace by *H*, leaves the room by *C*, and re-enters the furnace.

In summer only is the heated draught-chimney in use, and the valve open at *K*. The opposite practice would probably prevail among us, where open windows are so much favored; but the use of aspiration, even in summer (perhaps more so than at any other time), is very desirable in schools.

Pulsion is effected in a variety of ways—by pneumatic wheels, by pistons, by bells plunged in water, by jets of steam or compressed air urging a current of air, etc. The most common methods for buildings are those which use a helix (screw) or fan.

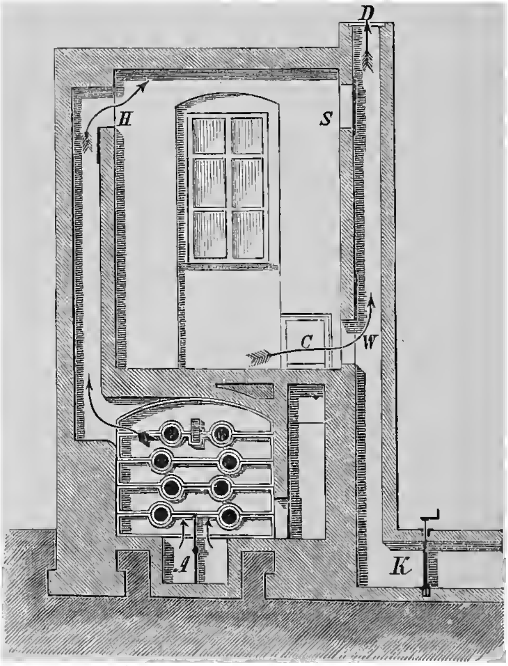

FIG. 31.—Winter ventilation.

While extraction by a chimney is apparently a more natural method, the application of mechanical force in pulsion (or extraction, for it is equally applicable to either) is said to be less costly under many circumstances. Degen considers that economy is gained by using a machine run by steam, instead of a draught-chimney, in most cases where there are over one hundred inmates in a public institution. Péclet, in similar cases, speaks of the cost of aspiration as much greater than that of the interest on the price of the machine, with expenses for repairs, wages of fireman, and fuel. For small schools, and for dwellings, it is not likely that machine-ventilation will be found suitable; but in larger schools, and in halls of assembly, the mechanical method is very desirable. Its advantages are the following:

It gives a definite and certain result each hour, uninfluenced by differences of the temperature, and susceptible of being watched over at all times. It is free from the influence of the wind, which very largely influences the action of a chimney, and may cause one to draw twice as much as another at the same time and place, if the exposure is different. Even reversal is possible in well-arranged chimneys, though not if they are kept well heated.

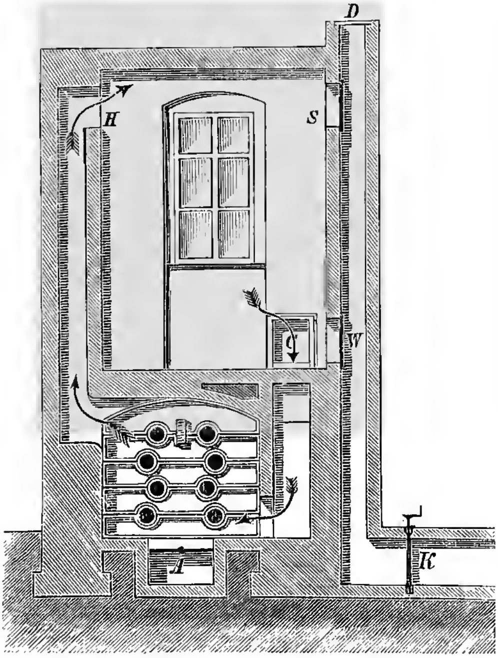

Fig. 32.—House closed.

The Johns Hopkins Hospital at Baltimore is furnished with means for extraction, by two chimneys, and for propulsion, by a fan. In regard to the former, the report of Feb. 12, 1878, states that—

"The experience gained by daily observations, continued over rather more than one year, on the subject of the practical workings of the aspiratory system, goes to show that the movements of the currents are exceedingly diverse, and that the conditions presented at one time, and those at another, gave widely different results.

"A high barometer, and a low relative humidity, with either high or low temperature, seem to be the first essential, for a satisfactory unassisted aspiration [*i. e.*, without warming the chimney]; as the relative humidity increases, the aspiration flags, and, on days with the barometer below its normal average, and great humidity, it becomes necessary to employ assistance to the aspiration.

"The direction and force of the winds have shown themselves to be important factors in the matter. Aspiration in this building is always satisfactory with the wind from the points S. W., W., N. W., N., and N. E. As regards the remaining points of the compass, the reverse is generally true. This may, perhaps, be explained by the fact that the first-named winds are almost always dry, and the last more or less humid. Exceptionally we have good aspiration with an east wind; but it will then be found that the chimney is kept dry by means of the several fires.

"On very quiet days, with ordinarily high barometer, low humidity, and high or low temperature, aspiration, unassisted, continues good; while quiet days, with reversed conditions, give reversed results. From these observations, drawn from practice, it would appear that dryness is also an essential factor.

"One of the aspirating chimneys of this building receives into its central flue the products of combustion of a furnace used for the heating of water; the same flue is also connected with the kitchen range. One or both these flues are in constant use, summer and winter, night and day; consequently the chimney is kept quite or nearly dry, and its aspirating power is rarely at fault. The other chimney is not directly connected with any constant source of heat, particularly during the summer season, but is connected with the engine-furnace and boiler: all the waste steam from this source escapes by means of this flue, and, in the absence of heat, tends to condense upon the interior of the chimney, and renders it moist. As a consequence of this, and a lack of direct heat, especially in the summer season, the aspiration is frequently imperfect, and requires the use of a grate at the foot of the flue already mentioned.

"With the central flues well warmed by heat from any source, ensuring dryness, we have never experienced any difficulty in securing a good upward draught and satisfactory aspiration.

"Under the conditions of unassisted aspiration the upward movement of air in the chimneys, as determined by the anemometer, has ranged from a barely perceptible current to 387 feet per minute, the latter being the highest recorded velocity, and deduced from the mean of these observations made at three points of elevation. With brisk fires burning at the bases of the chimneys, and an average temperature within the same of 82° F., the highest recorded observation is 700 feet per minute. I consider a mean velocity of 180 feet per minute to be nearly a correct average for long periods, under the usual varying conditions, and including both natural and assisted aspiration."

Distribution of air.—The openings and ducts in ordinary buildings are almost invariably too small. Frequently they lead to no outlet. In some cases sufficient channels exist; but, from motives of "economy," no heat has been supplied to warm them. The air supplied may enter at a point just under the point of exit, so as to compel the closure of the latter in order to retain the warmth. The air may be derived wholly from a furnace which possesses no arrangement for mingling cold with warm air. In this case, when the register delivers too warm air, the only resource is to close it, and thus lose a good part of the supply of fresh air. In short, common sense is violated in all ways.

The usual place for the ducts is in the floor. The space between two joists is very convenient for the purpose. A hall or school-room may discharge its air through a set of small registers dotted over the floor at equal distances, each communicating with one of these flues under the floor. The air in these flues may be collected in a central trunk-flue, or in two side-flues running along by the walls; it then passes to the draught-chimney by a direct or circuitous path. The combination of channels for *discharge* in the *floor*, with openings for *admission* of warm air at the *ceiling*, is characteristic of Morin's system, which is, on the whole, probably the best.

The reader, however, must be aware that the opposite system is extremely common, and has some good reasons in its favor. It is usual, at present, in houses and schools, to place the hot-air registers near or at the floor, and the "ventilators" near or at the ceiling. A few of the points connected with this question will be here discussed.

1. Shall we warm the air before bringing it into the room? The answer is almost wholly affirmative. The introduction of air by windows must be considered as supplementary to a system of extraction or pulsion. Cold air, introduced in an amount sufficient to renew the contents of the room every fifteen minutes or less, as is often requisite in full rooms, would often be very dangerous to the inmates. Of course this statement is relative, and in the case of theatres, where a comfortable temperature has once been established, it will suffice to supply air at 50° or 60° F.

2. Shall we introduce the warmed air at the top or at the bottom of the room? Morin introduces it at the top, and expects to secure thereby an equable and somewhat rapid passage of the entire mass of air in the room from the upper to the lower level, where it is extracted by the suctional force of the chimney acting through the ducts and floor registers. There are some objections to this plan, which should be mentioned. In the first place, the heated air becomes considerably cooled before reaching the floor, which is very undesirable. This would not be much noticed in a room over another warm room.

On the other hand, an exclusive ventilation in the upward direction, allowing the air to pass freely through the roof or ceiling, may easily be believed to be wasteful of heat; such a method, however, is actually in use in various places, on a large scale, with success. A very good recent instance is found in the Boston City Hospital, in which the structure of the new surgical wards, and the results of a series of physical and chemical observations upon the contained air of one ward, as given in the words of Dr. Cowles, are as follows:

"The building in which the observations were made contains one ward, 94 × 26⅓ feet in the clear, which has seven opposite windows and fourteen beds on each side. The windows have double sashes. The height of the ward from the floor to the centre of the arched ceiling is twenty feet, or an average of 18.42 feet. Each bed has a floor-area of 88.45 square feet, and an air-space of 1,629 cubic feet. The total air-space of the room is about 45,600 cubic feet.

"There is an open free air-space, containing only heating-apparatus, under the ward. The cold air is introduced through openings in the outer basement walls, and passes immediately over the steam-radiators, of which there is a separate one for every flue. The air then enters the ward only through openings under each window—fourteen in all—each inlet equal to one square foot of clear opening. Each steam-radiator in the basement is encased with galvanized iron, forming a small chamber, in which a switch-valve directs the fresh air, so that it passes either through the coil, so as to be warmed, or unwarmed directly into the flue above. A wire attached to the switch-valve leads to the room above, where, by the use of a key, the valve can be adjusted to alter the temperature of the air entering the ward. The volume of entering air can be changed only by opening or closing a sliding-valve and covering the inlet through the basement wall; and this is under the sole charge of the engineer.

"The foul air escapes through five large openings along the centre of the arched ceiling, each about three by six feet—total clear opening, forty-nine square feet—into the ridge-chamber, and thence either through the free openings in the sides of the chamber, above the roof, or through five ventilators, each two feet in diameter, on the top of the ridge, giving a total of clear outlet opening of fifteen square feet. The side openings are closed in winter, when also the openings in the floor of the chamber can be partly or wholly closed, and the ventilation aided by the flues, fourteen in number, in the outer walls of the building. These side flues prove in practice not to work unless the openings in the ceiling are entirely closed. The ventilating-chamber is warmed, when necessary, by steam-pipes."

A series of observations were taken in this ward, covering the period of a week, the temperature of the outer air ranging from 18° F. to 49° F.; the humidity, from 31 to 100 per cent. of saturation; and the atmospheric pressure varying considerably. The hourly supply of air per bed was found to be continuously something more than nine thousand cubic feet. Great uniformity of the air-supply was observed, which was secured by adjusting the slides covering the fresh-air inlets, once, twice, or three times a day. Taken with all previous observations, the average of eight thousand cubic feet per head per hour was found.

Analyses of the air for carbonic acid, by Professor Edward S. Wood, made between December 10, 1878, and January 19, 1879, gave the following results:

Location.	Number of observations.	Average percentage of CO_2.
External air	10	.0325
Centre of ward, two feet from floor	10	.0447
Side, between beds, two feet from floor	9	.0461
Centre, twelve feet from floor	9	.0526
Side, twelve feet from floor	8	.0579
Above opening into ventilating-chamber	11	.0571

The fourth of this series was selected as lying directly in the track of the current of fresh air from the registers; its result (.0526 of CO_2) shows that the current had become thoroughly mixed with the air of the room before reaching that point. In connection with other experiments, a constant upward motion of the whole air of the room seems to exist, with constant replacement by fresh air, permitting no stagnant areas, and with excellent diffusion of the fresh air and dilution of the foul air.

Allowing for the presence of thirty-eight persons in the ward, the air was changed effectively 3.81⅔ times per hour per head, or 91½ times in twenty-four hours. The measured volume of air entering was an average of 5,894 cubic feet per head, against 4,580, calculated from the respiratory impurity, showing that 78 per cent. of the entering air is actually utilized, and that its diffusion and the dilution of the foul air is excellent.

From the *general average* of all analyses made in the ward, the mean carbonic acid was found to be .0505 per cent., of which .0180 should be considered as originating in respiratory impurity; the air-supply per head, 3,333 cubic feet hourly; air of room effectively changed 2.77½ times an hour, or 66½ times in twenty-four hours. This is excellent ventilation.

It has been a question what part of the room contains the worst air, and for that reason is the most suitable place for extracting air.

Carbonic acid is often supposed to sink to the floor of a room by virtue of its superior gravity. Others have insisted that, as an ingredient of the mixed warmed gases of the breath, it possesses a levity superior to that of the air at 70°, and must rise to the ceiling. The latter is strictly the fact, from an abstract point of view. A higher percentage of CO_2 is often found at the ceiling than at the floor. This law, however, is greatly modified, in many cases, by the mixture with the air of the room which the breath must undergo in rising through six or eight feet of air, and also by accidental currents in the air, which drive it laterally back and forth.

Marcker,[1] in two examinations (of a cow-house and a stable for horses), obtained the following results, pointing to a great equality of diffusion :

I.

Height from ground. Metres.	I.	II.	III.	IV.	V.
1.45	.00132	.00074	.00171	.00090	.0007
3.00	.00139	.00075	.00171	.00086	.0007

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[1] Untersuchungen über natürl. Ventilation und die Porosität einiger Baumaterialien. Journ. f. Landwirthsch., 19. Jahrg.

II.

Height from ground. Metres.	I.	II.	III.
1.16	.00079	.00071	.00067
2.32	.00078	.....	.....
3.48	.00078	.00072	.00066

Breiting[1] made the following observations in a school-room. The figures give the number of parts in 10,000. A very steady increase during 45 minutes of observation is seen, while the difference between floor and ceiling is not so great as to be of practical importance.

Time in minutes......	0	5	12	17	22	29	32	37	41	45
Floor...............	6.56	....	7.45	....	8.01	....	8.32	....	8.68	....
Ceiling.............	....	7.13	....	7.86	....	8.09	....	8.48	....	9.01

Schürmann[2] has a table of sixteen observations upon the CO_2 in the air of workshops and bedrooms, which tend to support Pettenkofer's statement, that the proportion is greater at the ceiling than at the floor.

Parkes simply states that, according to Lassaigne, Pettenkofer, and Roscoe, the carbonic acid of respiration is equally diffused through the air of a room.

An illustration of the way in which diffusion of carbonic-acid gas occurs in a room was attempted by Forster and Voit.[3] In a room, containing about 6,700 cubic feet of air, two or three kilograms of carbonic acid were produced as rapidly as possible by pouring bicarbonate of soda into concentrated sulphuric acid. When the gas ceased to escape, the air of the room was tested at the floor, the middle, and the ceiling, at three points on each level, making nine simultaneous observations. One observer was stationed at each point, and all remained at their post without moving for fifteen minutes, when the test was repeated. By these precautions a tolerable freedom from accidental currents of air was secured. The contents per 10,000 were found to be as follows :

	First observation.	After 15 minutes.
Ceiling...............	28 vols.	40 vols.
Middle...............	16 "	32 "
Floor.................	233 "	214 "

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[1] Unters. betreffend den Kohlensäuregehalt der Luft in Schulzimmern, Basel, 1871.

[2] 4. und 5. Jahresber. der chem. Centralstelle für öffentliche Gesundheitspflege in Dresden.

[3] Zeitschrift für Biologie.

The amount at the floor had, therefore, lost only $\frac{1}{12}$ of its contents in CO_2 in fifteen minutes.

One of the chief objections to aspiration by heat, considered as a sole reliance, is the fact that it cannot be depended on for an emergency requiring a great but temporary increase of ventilating power.

Herter gives his opinion as follows: "The choice between the different systems depends upon the severity of the requirements, and upon the site and construction of the building. Different ones may produce a nearly equivalent effect, under various circumstances. Aside from this, mechanical pulsion, combined with simple (or, better, with mechanical) aspiration, deserves the preference. This combined system works with more certainty and constancy, delivers a better quality of air, is accompanied by fewer inconveniences, is easier to oversee, and in large edifices is cheaper, than other systems in the same circumstances.

"The other systems may be mentioned as valuable in the following order: mechanical pulsion, mechanical aspiration, aspiration by difference of temperature, ventilation by mantel-stoves in connection with Sherringham's and Arnold's valves, Galton's ventilating-stove, ridge-pole ventilation, and, finally, Watson's, Kinel's, and other similar ventilators in connection with Wolpert's caps."

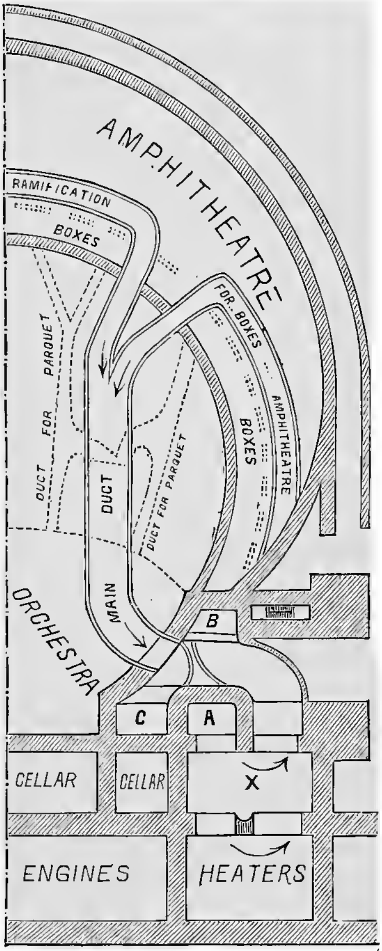

FIG. 33.—Scheme of ventilation of the "grande salle des fêtes" (Trocadéro) at the Exposition at Paris, 1878. Ground plan: A, shaft to admit air; X, place for fan, to draw air from A and send it to B; B, shaft leading to dome, where it enters the auditorium; C, shaft to receive foul air from ducts in floor for expulsion.

One of the latest applications of this combination of pulsion and extraction is found in the palace of the Trocadéro. This building seats an audience of 5,000 persons. The problem placed before the architects was, to furnish 40 cubic metres of air per hour to each person, or 200,000 cubic metres in all—that is, 56 cubic metres per second, or nearly 2,000 feet.

In the first place, the direction of the currents of fresh air was to be determined. It seemed at once evident to the designers that the quantity named could not be introduced at the level of the audience without causing serious inconvenience; while that amount, if extracted by floor ducts, need cause no perceptible draught, as the effect of air entering is very different from that of air in the act of leaving a room. For the purpose of extraction, 5,000 openings were made in the floor, to secure the greatest possible regularity in the process.

The next question was: "Shall it be propulsion or exhaustion?" The latter would have given rise to very disagreeable draughts, whenever any doors for entrance into the auditorium were opened. This objection does not exist in the case of propulsion, and propulsion was therefore adopted; but it was calculated that excessive friction would be developed in the working, and that an increase of atmospheric pressure in the hall would be produced, equal to 6 millimetres of water or 6 kilograms to the square metre, with tendency to abnormal exit of air by crevices. The objections on this ground were overcome by adding extraction to pulsion, thereby "decomposing the pressure into two, a positive and a negative"—a pressure inward at the point of introduction, and a "suction" outward at the point of exit.

Three chimneys or shafts are placed in a space between the auditorium and the outer wall of the house. Shaft *A* introduces pure air: it descends to the lowest part of the excavations under the house, and rises to the highest point of the roof, and receives air by registers at suitable points, or at will directly from above the roof, or from the underground regions, where there is perfectly pure air, and a vast surface for cooling it in summer or warming it in winter. This gives an economy of fuel. *B* is the shaft which conveys the fresh air to the top of the building (it is forced into *B* by a fan at *X*), where, passing through the central spherical calotte in the vault, it is thrown into the upper part of the auditorium and descends to the floor. Then it passes through ducts to *C*, a third shaft, where a second fan forces it up to the central lantern on the top of the grand hall, where it is discharged.

In order to equalize the friction in all the floor-ducts as far as possible, they have been arranged in a tree-like form, so that the air in each minor duct shall have an equal distance to pass before reaching the fan. The seats near the main outlet are not ventilated directly into the principal conduit; but all converge to a sort of centre of gravity or mean point in the surface of the parquet or boxes.

The aspirator-ducts terminate in the hall in vertical tubes, pierced at different heights, which prevents their being closed by dust, or by the dress of the audience. The tubes occupy the triangular spaces between the backs of adjacent chairs.

The ventilating-machines used for mines were found too noisy, and in most cases far from satisfactory in performance. The helix was therefore chosen as the most simple, economical, and noiseless.

Contrary to what might be anticipated, the air from the underground regions was found uncomfortably cool in summer weather, and had to be used very sparingly; a lowering of the temperature of the hall 3° or 4° (C. or R.) below that of the outer air became at once a source of annoyance to the audience, even on warm days.

"It is in the docility of the mechanical organs employed that the superiority of the system resides." [1]

The new opera-house at Vienna receives its supply of air from the basements. In the figure, P represents the point for admission of air. A helix, driven by a fan of twelve horse-power, forces the air by seven pipes from the lower to the upper cellar, whence it is discharged into the parterre and boxes. The pipes measure one metre in diameter; the machine is capable of furnishing, according to need, from 40,000 to 120,000 cubic metres of air per hour.

Between the lower and the upper stories of the cellar is a story in which the air, in winter, circulates and is heated, before being taken up into the upper cellar. The middle story is marked C in the diagram.

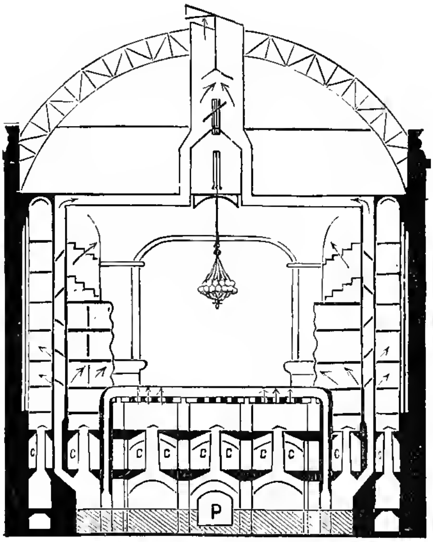

FIG. 34.

The pipes are seen provided with covers for regulating the amount of air passing to the upper cellar, and therefore controlling the ventilation of the hall. The subterranean chambers are of use in cooling the air in summer and warming it in winter. The building is well known as a successfully ventilated structure.

A somewhat expensive, but seemingly successful attempt to supply fresh air where it is most wanted, has been made in an opera-house in

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[1] The description and figure are taken from "Le Palais du Trocadéro," by special permission of Prof. Wm. Watson, member of the jury.

Chicago. It consists of a set of jointed metal tubes like the orifices of little hydrants, one of which is supplied in front of each seat, and can be turned by the occupant so as to send its jet of fresh air in his face, or in some other direction if desired. Force is used to drive the air into the hall.

The ventilation of the Hall of Representatives of the United States presents valuable points for consideration. In the following statements use has been made of Robert Briggs' report.

The hall requires no heating, being surrounded by corridors and rooms which are always kept at summer heat, and with a warmed basement and a ceiling well protected by a large air space covered with a copper roof. The problem is, rather, how to cool the hall, with inmates numbering from 500 to 1,600, and how to introduce from 50,000 to 100,000 cubic feet of comparatively cool air every minute among and in comparative proximity to these persons without producing a sensible draught.

"After much deliberation it was concluded to attempt the supply of most of the air for ventilation from registers (mouths of entry placed in and about the lower floor of the hall), and to permit the galleries to derive their supply mainly from the columns of air ascending from the space which they surround. The nearest approach to a uniform distribution would, of course, have been attained by the perforated floor and porous carpet of the House of Lords, England; but the habits of our people in the use of tobacco put this method out of the question, and the same objection attached to numerous small open registers, and the best arrangement seemed to be a compromise. The floor of the hall had platforms or wide steps, upon which the seats of the members are placed, and which are so constructed as to form semicircles around the Speaker's desk (the desk being placed in the middle of one side of the hall), and there were three radial inclined, and two other straight passages or aisles, which led from the highest platform to the forum—Speaker's desk—in front and at the sides of the floor. The arrangement . . . . gave seven risers of three inches high each. The aisles began with a step of seven inches rise, and thus had a very gradual descent of fourteen inches to the forum; and the construction gave an end or side riser of varying height where each platform joined the aisle.

"For the purpose of avoiding the abuses of horizontal gratings or registers, and yet to preserve the vertical direction of the currents of air, these end risers to the platform (side risers on the aisle) were availed of, as the places of entrance of fresh air; and as the aisles were but three or four feet in width, the strong horizontal currents from the opposite sides would encounter and neutralize each other: the intermingled air would have the desired direction upwards, and be so much spread out as a vein of air, as to have a relatively low velocity of ascent. This arrangement gave three main radial sheets of ascending air in the body of the hall, and another main sheet of the same kind along the side on which the speaker's desk is placed. Other registers were placed at the base of the gallery wall, which were screened by covers opening downwards; and to provide an ascending current in the corners, outside the semicircle of the platforms, large floor-registers were subsequently inserted in each of them. . . . . Much the greater part of the air was made to enter at the floor of the hall, so that members had the advantage of the first entry of air into the room. This distribution of the registers provided that in no case was a current of air directed against any person occupying a seat in the hall, either on the floor or in the galleries.

"The velocity of flow through the apertures in the gratings was very high (*i. e.*, 40 feet per second with summer ventilation of 100,000 cubic feet per minute), but within three or four inches of the apertures the velocity would fall off three or four times, by enlargement or spreading of the stream of air, while the practical result of the opposing currents was to make, at each aisle, a main ascending sheet of eighteen inches to two feet in thickness, within two feet of the aisle floor.

"The proper vertical direction and uniformity of upward flow of air in the hall was insured by the judicious placing of numerous small outlets in the iron and glass ceiling; . . . . the rate of outflow was very low, but the volume, as measured by the anemometer, was found to correspond fairly with that which was impelled by the fan at any given time."

A change was subsequently made in this arrangement, by which the platforms were extended over the aisles. To replace the aisle-ventilation, a great many small circular registers were placed in the floor of the platforms in front of the sofas. The direction of the currents was upward; and the ventilation proved satisfactory. A later change, which proved very unsatisfactory, is described as follows:

There are seven semi-circular platforms, each four feet five inches wide, with a front riser four inches in height. In the risers is placed a continuous band of small holes, each two inches high and one inch wide, and one inch apart, for supplying air; each member has the power of shutting off the air by registers. The air emerges as a thin horizontal sheet from the upper risers and is directed over the face of the platform below; traversing the platform, the sheet receives an augmentation in thickness from the next layer of air which escapes from the next row of holes, and so on until the whole seven platforms are swept over; forming a broad sheet of air directed against the back of the legs of those who sit on the platform.

The necessary velocity and coolness of this air are such that great discomfort is felt. The alternatives were to stop the entrance of air (which was equivalent to want of air for breathing, as at present); or to heat the air to a temperature (95° to 100°), which would feel comfortable on entrance, when the air of the hall became unbearably warm.

There is a fan for exhausting foul air, which, as tested by a member of the commission, extracted 25,000 cubic feet per minute; of this amount 15,000 was furnished to the hall by the fan of supply, and 10,000 must have leaked in at various points from the corridors. These figures sufficiently explain the poorness of the ventilation.

Railroad-cars.—The difficulties in ventilating these places are obviously great, and the results, at present, are bad.

In the report of Fisher and Nichols (op. cit.), the results of a large number of analyses for carbonic acid are given. The averages of these are as follows (in parts per 10,000):

Series.	Place.	Average.	Maximum.	Minimum.
1.	Smoking-cars.	22.8	36.9	12.7
2.	Passenger-cars.	23.2	36.7	17.4
3.	Smoking-cars.	17.0	...	...

It is stated by Lang and Wolffhügel that the pollution of air in cars is not so quickly felt as in chambers. Repeatedly they have examined air which seemed to them fairly good, and which the passengers spoke of as good, and found it to contain a much higher percentage of CO_2 than air of a similar quality possesses in rooms. Air which contained fifteen parts in 10,000 of CO_2 was sensibly fresher than air of rooms containing only ten parts. An analogous fact is noticed by Voit. The air in the lead-chamber may have over ten per cent. of CO_2 without causing discomfort. The explanation offered is the natural one, that air under such circumstances in small rooms is changed very rapidly, and that in consequence the putrefactive change of the animal exhalations, to which the oppressive sensation is ascribed, does not have time to occur.

If this may be assumed, the requirements of a railroad-car are less exacting than those of dwelling-houses.

In the equation

$$y = \frac{k}{p - q}$$

we may therefore allow that

$$k = .20 \text{ litres.}$$
$$p = .0015$$
$$q = .00035$$
$$y = \frac{20}{.00115} \text{ litres} = 17.4 \text{ cubic metres,}$$

or about 600 cubic feet per head and hour.

If we accept Lang and Wolffhügel as authority upon the point of "sensible purity," the requirements in railroad-cars are only for a third or a fourth as much *fresh* air as in the case of halls. We should remember, also, that the standard of purity (6 or 7 per 10,000) is only a subjective one.

The American passenger-car, with an average cubic space of about 2,500 feet (exclusive of that occupied by furniture and the bodies of passengers), and holding about seventy-five persons, would therefore require *at least* 750 cubic feet of fresh air per minute; we will say, 1,500 cubic feet, or more than half the contents of the car. The introduction of this amount without draught is a matter of much difficulty.

The opening of windows is of course an entirely unreliable method of ventilation. The valves in the end doors and windows expose passengers to severe draughts, and are, therefore, usually closed. The ventilating apertures in the top and letter-line are found "entirely inadequate" (Nichols), or else they produce an improper draught.

It is not difficult to bring into the car a large quantity of air by means of cowls or revolving caps placed on the roof, or by end windows. Both these devices act only while the car is in motion or exposed to a wind; but as the car is scarcely used at other times, this forms no objection to the use of such methods. The problem remains, how to distribute the air without draughts; the solution is to be found in the use of extensive perforated surfaces for distribution. Kedzie recommends two or three such plans. In one, the air is first sent to a space below the floor of the car, where it has to deposit its impurities in a tank of water; it then ascends to the roof again, where it is sent into cylinders, running the length of the car at the height of the roof, from which it escapes by numerous small holes. The cylinders are so arranged as to be turned, giving the escaping air various directions—downward, sideways, or upward, as may be desired. In another plan the air is brought in at the end of the car under the eaves, the entrance of cinders being prevented by fine gratings. The distribution occurs along the whole length of the roof, through similar fine apertures. The space for distribution in this case is formed from the "monitor story," which is provided with a floor that shuts it off from the car; in this floor are the perforations for air.

An excellent auxiliary to these systems is formed by a hood placed below the floor, and sucking the air out of the lower part of the car (*appel par en bas*). The space under one of the seats may be boxed around, to form an enclosure into which the hood opens; the air escapes first (through gratings) into this space, then into the hood.

A system, mentioned by Prof. Nichols, consists of a fan-wheel, carried by a pulley attached to one of the axles, which forces air into the car, through a strainer of wire-gauze, at the first side-window. The air is conducted around the roof in a six-inch pipe, perforated at proper intervals, and finds its exit through registers in the floor. It has been found that when the car had been completely filled with smoke, it was thoroughly cleared in about six minutes by this method. If this mechanism can be trusted to run with regularity, the method is a better one than that which depends on the hood.

Dwelling-houses.—A few special points may be spoken of under this head, although, in general, all that is necessary has been said elsewhere.

Many dwellings are well ventilated for daily life, but few have any provision for the emergencies of evening assemblies. Upon such occasions as the latter, extreme discomfort is often felt from the heat, the excessive moisture, and the closeness. Great relief can be had by providing an escape for the products of the combustion of gas, by methods figured under Hospital Construction. A chandelier (gasolier) may discharge its heated products either by a closed tube and globes, which carry off everything, or it may discharge in a manner less complete, yet sufficiently so for the purpose, through holes in the ceiling above. An ornamental piece of stucco over the chandelier may stand out an inch or two from the ceiling without appearing to be separated from it; the space thus given, in a circumference of six feet, equals an aperture of one-half a square foot, or one foot, which will give exit (at a velocity of six feet per second) to ten or twenty thousand feet per hour. Two such openings (discharging, say 40,000 feet) would be of material service; at least they would aid greatly in getting rid of the heat and the smell of gas. The actual requirements of one hundred people in a drawing-room would equal from 4,000 to 10,000 metres per hour: say from 140,000 to 350,000 cubic feet. Evidently, therefore, other means must be used in addition to that above named. Two fireplaces may exhaust 40,000 feet more, which still leaves us inadequately provided for. The usual flues may be inserted in addition, in connection with or adjacent to the chimney; but it will be necessary to attend to the warming of such flues, as otherwise they may simply serve as inlets for cold air in undesirable parts of the room.

For sleeping-rooms, in mild climates, hollow iron-bricks may be used, an equal number at the top and at the bottom of each apartment. The Sherringham valve may be applied to these, but so as not to close them wholly.

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GENERAL PRINCIPLES

OF

HOSPITAL CONSTRUCTION.

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GENERAL PRINCIPLES OF HOSPITAL CONSTRUCTION.

HOSPITAL construction may properly be considered a subject for special study, and one so near the confines of medicine and architecture as to call for careful investigation from the members of both these professions. The subject naturally includes several divisions, all of which bear intimate relations to each other, and, while it is difficult to discuss either branch without reference to the others, it seems desirable to consider the subject mainly under the following heads :

LOCATION, OR SITE.
GENERAL CHARACTER.
MATERIAL.
GENERAL ARRANGEMENT AND DISPOSITION.
ARRANGEMENT OF THE SEVERAL PARTS IN DETAIL.
MEANS OF HEATING.
VENTILATION.
DRAINAGE.
COTTAGE OR VILLAGE HOSPITALS.
BIBLIOGRAPHY.

There are numerous allied topics which are of vital importance to the well-being of a hospital, which are so recognized by physicians both in theory and in practice. A well-built hospital poorly organized may be the home of disease and the nursery of fatal hospital maladies. But the consideration of the organization, management and furnishing of hospitals, as well as their relation to medical schools and training-schools for nurses, has been purposely avoided, as foreign to the general scope of this paper. The study of hospitals for special objects, as for instance insane, lying-in, military, children's and similar institutions, is also omitted, the main object of this paper being to inculcate general principles applicable to all institutions for the care of the sick.

SECTION I.

LOCATION.

The location of a building where the sick are treated should be one which commends itself in an eminent degree as a *healthy* one : that is, the site should be elevated ; on a good, porous, gravelly or sandy soil ; not on new-made land or on a clayey or retentive soil ; where abundant means are offered for effective drainage ; not in a crowded locality, but in a situation which is open to healthy winds and has a free exposure to sunlight. The building should be so situated that the prevalent winds may not pass over marshes or regions affected by dampness or malarial influences, or in the neighborhood of large sewers.

Particular attention should be given to the slope of the land in the neighborhood. A valley or a depression should be avoided, as well as a situation under a steep hill, or on a slope which would collect water or dampness, or where the air would have a tendency to become stagnant. Such a site should be selected as will give a clear area of eighty patients to the acre, as advised by the Chirurgical Society of Paris, or, at most, of one hundred patients, as is sanctioned by English usage.[1]

In testing the site due regard should be given to the mortality of the region. In this estimate, however, it may be necessary to consider the financial and social condition of the inhabitants. The poverty of those living in a region, or the risks arising from hazardous employments, may increase the mortality in an undue proportion. It would be manifestly unwise, however, to disregard the fact of a large general mortality in a neighborhood, irrespective of the social condition of the inhabitants. A careful investigation of the locality would probably disclose the existence of unsanitary influences which would be prejudicial to the recovery of the sick.

The general question of location and construction is tersely put by Hennen : "That building makes the best hospital which is situated high, dry, and detached ; in which there are sufficient doors and windows admitting of cross-ventilation ; with open fireplaces and secure roofs and walls ; with rooms of easy access, lofty and of moderate size."[2]

The question may well be asked whether or not a hospital should be located within the crowded portions of a city. Various reasons exist which render it difficult to treat the sick poor of a large city anywhere except near their homes, at least those who are seriously ill or injured. "No site, however accessible, should be selected which will not give at all times the utmost purity of atmosphere. If, however, this desideratum can be obtained, we may join with it the advantages to be derived from

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[1] Galton : The Construction of Hospitals. Leeds, 1869.

[2] Hennen : Principles of Military Surgery. London, 1829.

the possibility of conveying the sick and wounded in the most satisfactory manner to the hospital: the accessibility of the institution to the medical officers and the friends of the patients, and the convenient position of the medical schools, if they exist."[1]

"All of these elements are of importance—every one in its place. It is obviously of no use to build a hospital in the best air in the world, if neither patients nor medical officers can get to it. It is only in applying common sense to such a question, and by always giving a preponderance to the condition of highest importance, namely, pure air and space, when the other considerations can be at the same time reasonably obtained, that the best will be done for the sick."[2]

The inconvenience of treating cases of accident or of sudden illness at a distance from a large hospital may be in part overcome by the establishment of reception hospitals, of a few beds each, at suitable points. These should be placed near large manufacturing establishments, and in crowded localities occupied by the poorer classes. It should be well established, however, that these smaller hospitals are for temporary use only, and should be subsidiary entirely to the larger hospital of which they form a part. Every well-organized metropolitan hospital should have one or more easy ambulances, made to fit the horse railroad tracks, to be summoned by telegraph from the police stations or otherwise; with such means of conveyance, the distance of the hospital from the more thickly settled portions of a city becomes a matter of secondary consideration to those of space and pure air.

The question of expense necessarily enters largely into the question of location. The land in the closer parts of a city is too valuable to enable us to carry out the most approved methods of building, and we find city architects forced to yield to the requirement of placing patients in many-storied buildings, to their manifest detriment. The question is merely one of obedience to natural laws—for the best welfare of the patients they must be placed under the *best* hygienic conditions—whatever expense or inconvenience such condition may render necessary. It is not enough to say that the air of our cities is good; the air of the suburbs or the country is *better;* under the best possible circumstances, the air of the hospital is no better than the air of the streets which surround it.

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[1] Bristowe and Holmes: Sixth Report of the Medical Officers of the Privy Council. London, 1863.

[2] Nightingale: Notes on Hospitals. London, 1863.

SECTION II.

GENERAL CHARACTER OF THE HOSPITAL.

The requirements of each city or town must decide the size of its hospitals. They may appropriately be classed as large hospitals, when they contain from one hundred beds upward; of medium size, when they contain from twenty-five to one hundred beds; and cottage or village hospitals, when accommodations are provided for from three to twenty-five patients. The exigencies of war may call temporarily for immense hospitals, but modern investigations show those of more moderate dimensions to be better; they more nearly approach the home-life which gives to each patient the best means of recovery; they insure the wider separation of the sick of a city; and it may safely be assumed that in such smaller institutions the patients are more satisfactorily attended.

Sir James Simpson presented his views of hospitalism in a series of propositions which disputed, in nearly every instance, ideas of hospital hygiene and management previously held. While he took the result of hospital amputations as the means of deciding the point,[1] Dr. Evory Kennedy, of Dublin, in a paper presented to the Obstetrical Society in 1869, reached the same end by his statistics on zymotic and puerperal diseases. "Surgeons are little inclined, at this day, to undertake ovaritomy in large general hospitals, and the precautions taken by Mr. Baker Brown in his operations meet the approval of most physicians."[2] While larger hospitals offer greater advantages for clinical instruction and give more éclat to officials connected with them, the smaller establishments are, without doubt, most advantageous to the patient. The same principle, the wide distribution of the inmates of an institution, would seem to require that they should be accommodated in many rather than in one building. No single hospital building ought, under any circumstances, to contain more than one hundred patients under one roof. It may be considered admissible, under extreme circumstances, to have four pavilion wards in two stories, on either side of a central administrative building, with twenty-five patients to each ward. Even this number is not advisable, but with more than this number the detached plan is unavoidable. In the view that patients are best treated in *one-story detached pavilion wards*, all recent writers on the subject are agreed, and the determination of this point may influence the decision regarding the large or small size of the institution. The system of breaking up the aggregate of patients and placing them in small wards necessitates the purchase of more ground, there are more roofs to construct and keep in repair, the administration becomes somewhat more difficult, and more fuel is called

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[1] Simpson: Hospitalism. New York, 1872.

[2] Chadwick: Art. Boston Medical and Surgical Journal, April 8, 1875.

for. But the object in erecting a hospital is to provide for the best good of the patients for many years to come, and if this end cannot be attained without crowding, it is far better to reduce the size of the hospital, or to place it where land can be obtained at a lower rate.

Three forms of buildings have been used for hospitals; they are called the pavilion, block and corridor systems. The first, or *pavilion system*, includes wards, either long or nearly square, of one story or many, detached or united, but which have windows on each side, and so offer the best means possible for air and sunlight. The second form—the *block system*—consists of buildings of conglomerate architecture, their

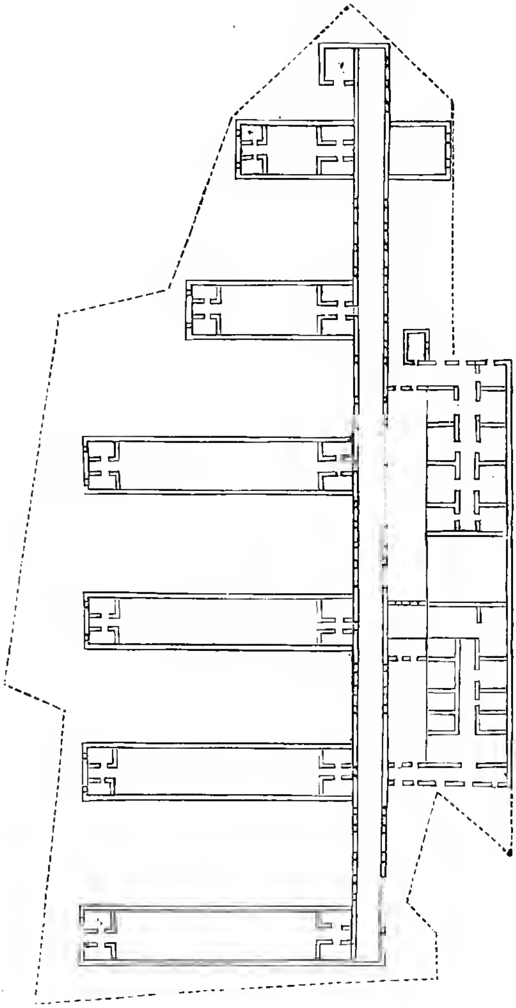

Fig. 1.—Ground plan of hospital at Malta.

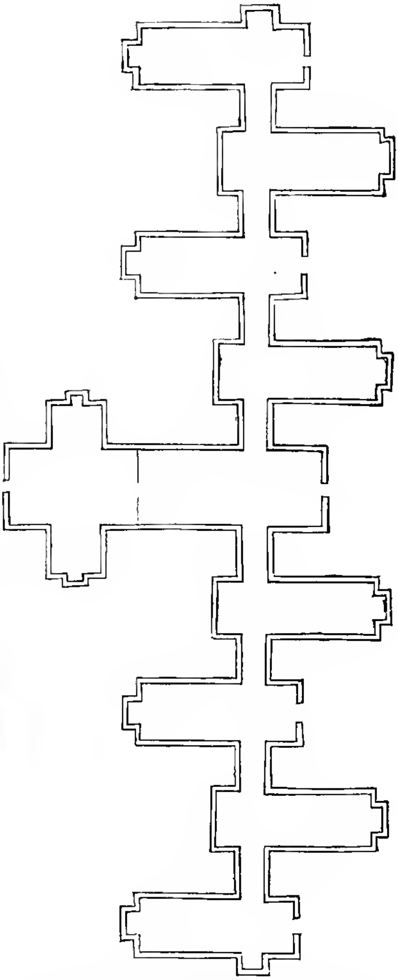

Fig. 2.—Ground plan of Blackburn Infirmary.

wards arranged in such a manner as to occupy the least possible space, with insufficient ventilation and exposure, and often opening into each other or placed back to back. The *block system* is that on which many of the older hospitals were built. The error of this plan was overlooked from want of a proper conception of the needs of the patients, especially in regard to their want of air and sunlight, and naturally arose from the custom of using any unemployed buildings, such as private dwellings, convents or churches for the purposes of institutions which, above all others, should be placed under the best hygienic circumstances. The *corridor system* bears a certain resemblance to that of the pavilion, the wards both being in a long building; but in all hospitals of this construction the side of the ward is covered by a corridor or hall, which connects different parts of the building and is used as a means of communication.

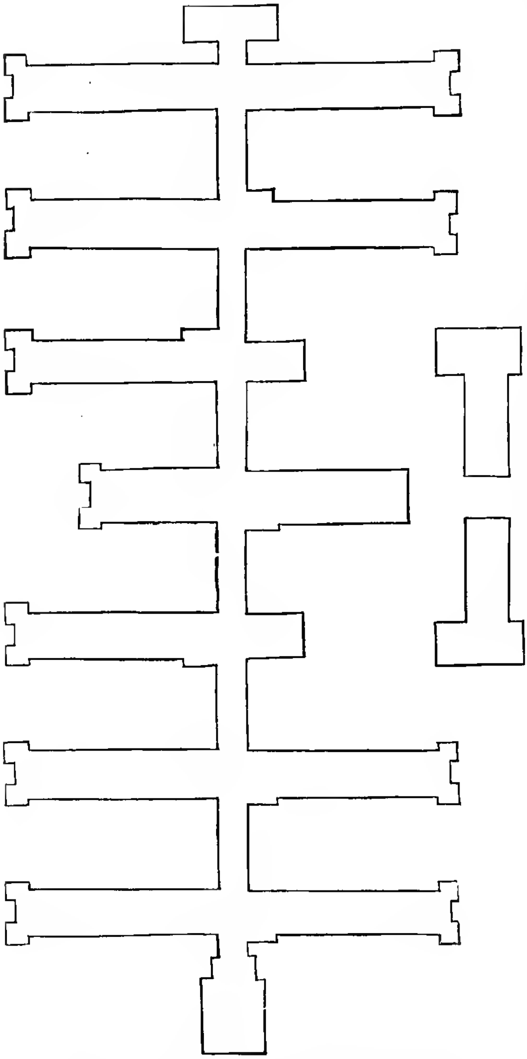

FIG. 3.—Ground plan of the Woolwich Hospital.

The most enlightened modern views have accepted the pavilion system as the most satisfactory. It not only has superior advantages as regards air and sunlight, but in its simplest form the pavilion is a hospital in itself, with most of the appliances needed for its separate administration. It can be adapted for use as a small village hospital, or may be indefinitely multiplied, as the space at command will allow, or the number of patients may demand. In many of the larger hospitals the pavilions are entirely detached. Ground plans are here inserted of the Hospital at Malta, the

Blackburn (Eng.) Infirmary, and the Woolwich (Eng.) Hospital, showing how the same pavilions may be compactly united on a limited extent of ground, and yet retain the advantages of the separate buildings. "A good illustration of the adaptability of this system to any site is afforded by the new hospital for one hundred beds, at Swansea (Eng). . . . In this case the site is triangular, and the administrative block, operating theatre, etc., are placed at the apex, which faces the prevailing wind, while the pavilions run down each side, and both sides of the wards receive sunlight and air."[1]

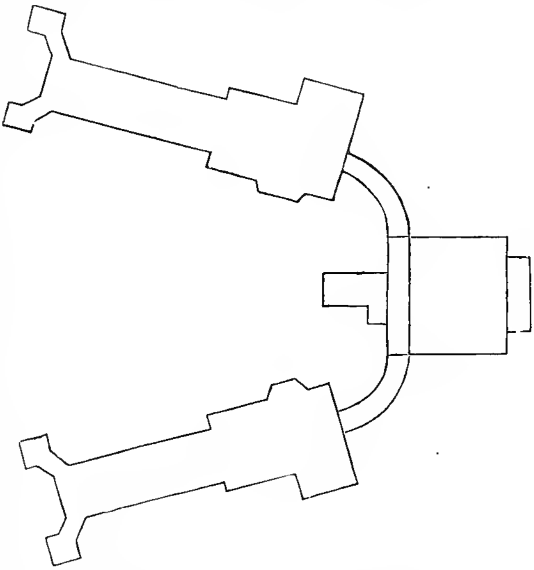

FIG. 4.—Ground plan of the Swansea Hospital.

"The true principle of hospital construction, as at present understood, was at first declared by a commission of the French Academy of Sciences in 1788, which made a final report as to the conditions which a model hospital should fulfil, specifying that wards should be in isolated pavilions, that each ward should be about 24 feet wide, from 14 to 15 feet high, and 115 feet long, and should contain from 34 to 36 beds, and that the windows should extend to the ceiling."[2]

A few examples of the block system, both of the general ground plan and of the disposition of single wards, are given. The first is a ground plan of King's College Hospital in London (Fig. 5); the others are ward plans in the old Marine Hospital at Woolwich (Fig. 6), the Portsmouth Hospital (Fig. 7), and the Hôpital de la Clinique in Paris (Fig. 8). All of these show marked errors; most of them have wards

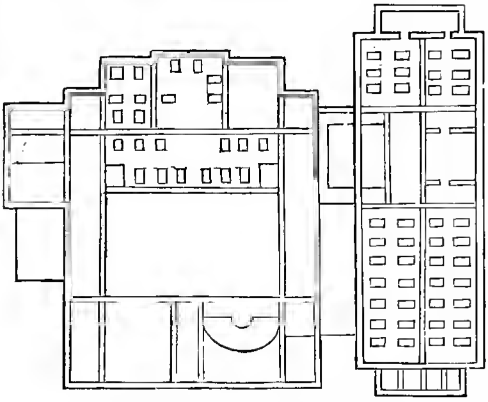

FIG. 5.—King's College Hospital.

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[1] Galton: Op. cit.

[2] Billings: Barracks and Hospitals. Circ. No. 4, S. G. O., Washington, 1870; and Husson: Études sur les Hôpitaux, Paris, 1862.

opening into each other, without suitable light or ventilation, with beds placed in rows against dead walls, or with but a single window for many beds.

The corridor system has the double disadvantage of interfering with cross-ventilation and of connecting the various wards in such a manner as to engender a common hospital air. A portion of the St. Antoine Hospital (Fig. 9) is given to illustrate the system. Both the block and the corridor systems tend to complicate the difficulties of management, to favor the stagnation of air, and to generate pyæmia and similar hospital pests. For the treatment of simple, non-infecting diseases, the detached pavilion system, of one or at most two stories, is the best; for the treatment of open wounds and the diseases of a possibly infectious character, the same system is decidedly preferable; and for contagious diseases, the tent, barrack, or hut, which is the simplest form of the pavilion, is absolutely called for.

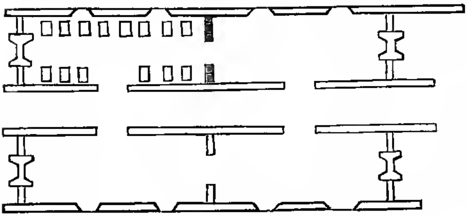
Ward plan.

FIG. 6.—Old Marine Hospital at Woolwich.

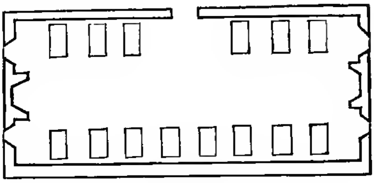
Ward plan.

FIG. 7.—Portsmouth Hospital.

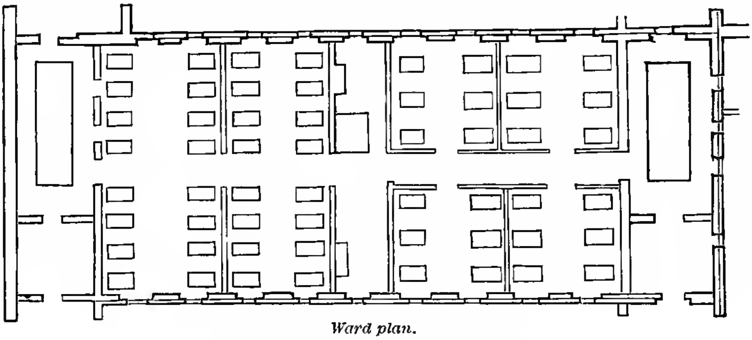
Ward plan.

FIG. 8.—Hôpital de la Clinique in Paris.

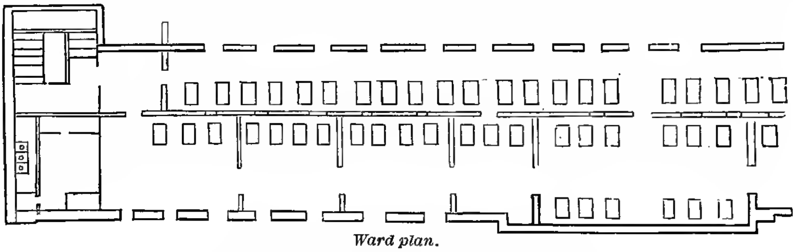
Ward plan.

FIG. 9.—St. Antoine Hospital in Paris.

SECTION III.

MATERIAL.

The plan which has commended itself most favorably to medical men of late years in establishing a hospital, whether of large or small dimensions, has been to build it of detached wooden pavilions, with an administrative building of more permanent materials. Unfortunately, physicians have rarely the privilege of building hospitals; and, even if they are permitted to suggest the plans, they find them so manipulated by trustees or architects that the essential points are, in many cases, thoroughly eliminated. It is not reasonable to suppose that architects will suggest, or committees of construction adopt a material which gives little opportunity for display, appearance of permanency, or the erection of an architectural memorial. The Surgeon-General of the U. S. Marine Hospital Service says: "The old, magnificent hospitals, built as monuments for all time, will be abandoned for the simple pavilion of indefinite existence; and the only strictly permanent parts of the modern hospital will be the executive building, kitchen, laundry, and engine-house."[1]

"I believe," says Billings,[2] "that no hospital should be constructed with a view to its being used more than fifteen years. If the money required to put up such structures as the New York civil hospitals, the Rhode Island Hospital, or the Cincinnati Hospital, were divided into two equal parts, one half being used to erect frame hospitals of the same capacity as the stone and brick hospitals actually built, and the other half being put out at interest at six per cent., a complete new hospital could be furnished every twelve years for an indefinite period."[3] Mr. Brook, one of the surgeons of the Lincoln County Hospital (England) is thus quoted by Erichsen: "Of late years the interior of the hospital has, at one time or another, been entirely renewed, but still the disease (pyæmia) kept breaking out; and it was the opinion of all past authorities that it lurked in the very fabric, and that nothing but demolition would remove it."[4] A French authority, in speaking of the American ambulance in Paris in 1870–71, says: "La mobilization des hôpitaux temporaires est

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[1] Woodworth: Annual Report of the Supervising Surgeon-General U. S. Marine Hospital Service. Washington, 1873.

[2] Billings: Barracks and Hospitals. Op. cit.

[3] The cost of the Marine Hospital at San Francisco, on the old plan, was $238,871; the one now in use at the port of Boston cost $394,047; that at Chicago, recently finished, on the old plan, $422,107; while upon the unfinished hospital at New Orleans $530,000 has been expended. The cost of the new barrack hospital for the Marine Hospital Service, at San Francisco, including the surgeon's residence and all the administrative buildings, is $58,789.

[4] Erichsen: Hospitalism and the Causes of Death after Operation. London, 1874.

un problème résolu."[1] Finally, Galton thus treats the subject in his work on the construction of hospitals : "I would add one more caution : Do not build for a long futurity. Buildings used for the reception of the sick become permeated with organic impurities, and it is a real sanitary advantage that they should be pulled down and entirely rebuilt on a fresh site periodically."[2]

Dr. Billings, in his recommendations to the trustees of the Johns Hopkins Hospital, after expressing the opinion that his views, previously quoted, may have been too sweeping in this respect, says : "I do not think it necessary that all the buildings of a hospital should be destroyed or removed at certain regular intervals, in order to prevent infection ; and there are some things to be taken into account in favor of more permanent structures under certain circumstances, to which I did not give sufficient consideration."[3] Dr. Folsom also, in the same work, says : "I do not consider destructible barracks, which are so excellent for military hospitals, at all suitable for a private, civil institution. I believe that careful administration will make permanent structures equally healthful with them, and, in a temperate climate, physical comfort is greater in a building with comparatively thick walls. I should consider the moral effect of barracks in a civil hospital, unless for temporary and exceptional use, particularly prejudicial."[4]

It should be noted that these views have not been definitely adopted by the trustees of the Massachusetts General Hospital in Boston, and the City Hospital in the same city, or by the authorities who control many of the hospitals in this country and in Europe, where destructible barracks have recently been built. It cannot be questioned that wooden buildings bring the patient nearer to the condition of nature, that such an arrangement is more satisfactory on the ground of expense, and that a barrack hospital can be more speedily and easily erected. It is no less true that any mismanagement in a permanent building is more liable to visit dire results on the patients than in a temporary structure. It should in fairness be said that such wards increase the liability to fire, that permanent buildings are more easily warmed in the cold season and are cooler in summer, and that, in some cities, the erection of wooden buildings would be prevented by statute or ordinance.

In an economic view this objection pertains to the more lasting buildings, viz., that architects are tempted, with permanent materials in their hands, to devote too large an expenditure to display and effect, making the buildings expensive in indirect proportion to the use for which they are intended. A hospital should never be an architectural monument, and any excess of funds should be devoted to extending its means for practical work. Simplicity, almost severe in its character, should mark

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[1] Nouveau Dictionnaire de méd. et de chir. pratique, Paris, 1873.

[2] Galton : Op. cit.

[3] Plans Johns Hopkins Hospital, New York, 1875.

[4] Ibidem.

its construction. Ornament increases the original expense and requires continued care and work.

If the building is made of wood it should, in temperate climates, be made double, with the purpose of keeping out the cold in winter and the heat in summer. and in order to afford additional means for ventilation.

Foundation and basement.—The foundations of the wards, whether built otherwise of destructible or permanent material, should be of brick or stone, sufficiently elevated to raise the lower floor six or eight feet from the ground. The surface of the basement should be on a level with the surrounding ground; its floor should be cemented, and the space thus created should be employed exclusively for purposes of heating and ventilation. It should in no case be employed for stores or for any of the offices of administration. In mild climates the space should be entirely open to the air, but in colder regions it may be enclosed by windows, which should be kept open as long as the weather will allow, and freely ventilated every day, even in the coldest season. It would be better that the lower story of the building should be supported on arches, as a security against damp and cold. In this case, in destructible buildings, the foundation would serve for a succession of buildings for many years.

In order to carry off as far as possible the drippings from the eaves and the rain which is driven against the sides of the building, and to prevent the water from reaching the foundations, the ground outside the walls should be paved or concreted for a space of at least two or three feet in width.

Damp-proof walls.—Little effort is made in this country to render the walls of buildings damp-proof. Pettenkofer and other recent writers give in figures the amount of water contained in the walls of a building at the time of its erection, or the amount which such walls are likely to absorb from a humid soil. This moisture may rise to a height of thirty feet, and must be given off by evaporation. To obviate the chance of such inconvenience, recourse should be had to some impervious material, which should be introduced into the walls about a foot or more above the surface of the ground. For this purpose a double course of slate, a course or two of enamelled brick, a vitrified stoneware tile, perforated for the admission of air, a layer of sheet-lead, or one of hot bitumen or asphalt, have all been employed with success.

Inside walls and ceilings.—The inside walls and ceilings must be covered with material which can in no way harbor organic or infectious germs. Experiments recently made by M. Broca and others show the presence of micrococcus and bacteria, of pus-globules, of spores of epiphytes and other organisms, in the air and on and within the material of the walls of wards that have been long used.[1] A case was reported to the French Academy of Medicine in 1862, in which an analysis of the plaster of a hospital wall gave 46 per cent. of organic matter.[2] Plaster, wood,

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[1] Revue méd. de l'Est, Revue de Thérap., Paris, 1874.

[2] Galton: Op. cit.

even paint and varnish, absorb the organic impurities given off by the body, and serve as a constant element of danger. As the safest of these, it is best to rely on sound plaster placed directly on the brick wall, or on iron laths or wire netting, allowed to become well hardened, and then covered with at least three coats of paint, and afterward varnished. Such walls can be frequently washed. A still better material than plaster is Parian cement. It is, however, costly, and is liable to crack, and thus harbor both vermin and animal emanations. Dr. Luther, in a recent article, suggests the employment of soluble glass in hospital construction. "In the building and arrangement of institutions, particularly those for the insane, who exercise little control over the urinary or intestinal discharges, no system of ventilation or arrangement of the apartments occupied by such patients, whether of wood, painted or oiled, or with floors of slate, metal, or cement, has been sufficient to effect entire cleanliness. A material having an entire absence of absorbing surface would seem to meet the demand in such cases, and glass is such a material. The walls, floors, and ceilings might be covered with it. It is not expensive, is strong when sufficiently thick, is impervious to water and dampness, and can be made of suitable color. Apartments thus fitted up could be thoroughly drenched with water, so as to remove every particle of fetid matter."[1]

The walls of the water-closets, lavatories, sculleries, kitchen, and laundry require equal care with those of the wards. The walls of the administrative and other portions of the hospital require no special notice.

Floors.—The floors of the wards and administrative departments must be made of narrow strips of close-grained hard wood, with matched joints blind-nailed. In permanent buildings they should be laid with concrete on iron beams, and be non-conducting as regards moisture and sound. The woods best suited to the purpose, in use in this country, are the hard pine and ash. The floor may be oiled, or may be treated with paraffin melted and poured upon it, and then ironed in by hot irons. Paraffin dissolved in turpentine may also be applied as a paint to the walls and furniture.

It is a little surprising that a sanitarian of the present day should recommend that the floor of the wards should be covered with tiles, "which may be covered with *good oil-cloth*, or material of the like kind, *which will not absorb matters and gases, and will lessen the necessity of washing the floors*, and which might be frequently removed and washed."[2] It is true that tiles are used as flooring in some of the recently constructed hospitals, but properly made wooden floors are certainly far preferable.

The floors of the water-closets and lavatories should be of slate, marble, or tile; the partitions between the water-closets, the wash-boards, and the mop-boards, should also be of the same material, to allow free sluicing of these apartments.

Throughout the hospital, cornices, projections and corners should be

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[1] Luther: Art. in Philadelphia Med. Times, Nov. 27, 1875.

[2] Jones: Plans for Johns Hopkins Hospital.

avoided; the tops of windows and doors should be rounded to prevent the accumulation of dust, and to facilitate cleaning; and the angle formed by the base-board and floor should be rounded off in the manner shown by Dr. Folsom in his suggestions for the Johns Hopkins Hospital. Thresholds are to be avoided. They are an annoyance to very feeble patients, and they interfere with the passage of cars for the conveyance of sick or injured patients, or for the transportation of food.

SECTION IV.

GENERAL ARRANGEMENT.

The arrangement of the hospital in gross is subsidiary, in general terms, to the arrangement in detail. The component parts of the "ward unit," which are to be specially borne in mind in the general arrangement of the institution, are the beds, the air-space (which must be sufficiently large for the proper treatment of each case), the superficial area, the water-closets, lavatory, nurse-room, and other necessary offices. It is the advantage of the pavilion system that this unit may be indefinitely multiplied, so that, with the appropriate administrative buildings, the hospital may be gradually enlarged to meet the needs of increasing population.

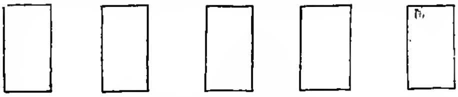

FIG. 10.

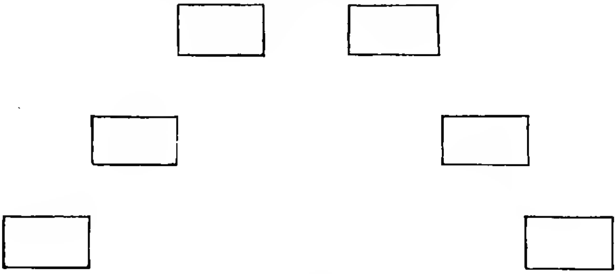

FIG. 11.

All hospital buildings should be placed nearly north and south, so that the sun may gain access to both sides on each day. The several buildings may be arranged, for economy of space, parallel to each other (Fig. 10),

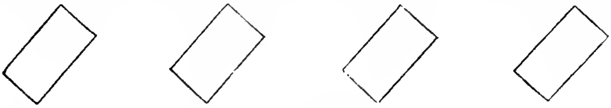

FIG. 12.

but never nearer than twice the height of the walls, and we think the advice of Dr. Wylie, to make the distance thrice the height, more satisfactory.[1] The experience of the war of the rebellion points to the arrangement of the pavilions *en echelon*, where space allows, as the most desirable in order to secure a free exposure to the wind, whatever way be its direction. The diagrams given in Figures 10, 11, 12 and 13, and the plan of the Herbert General Hospital (Fig. 14), show desirable positions for the separate pavilions.

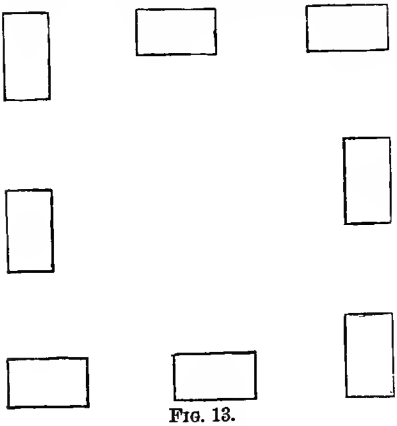
FIG. 13.

The extension of the pavilion in a direct line would theoretically ac-

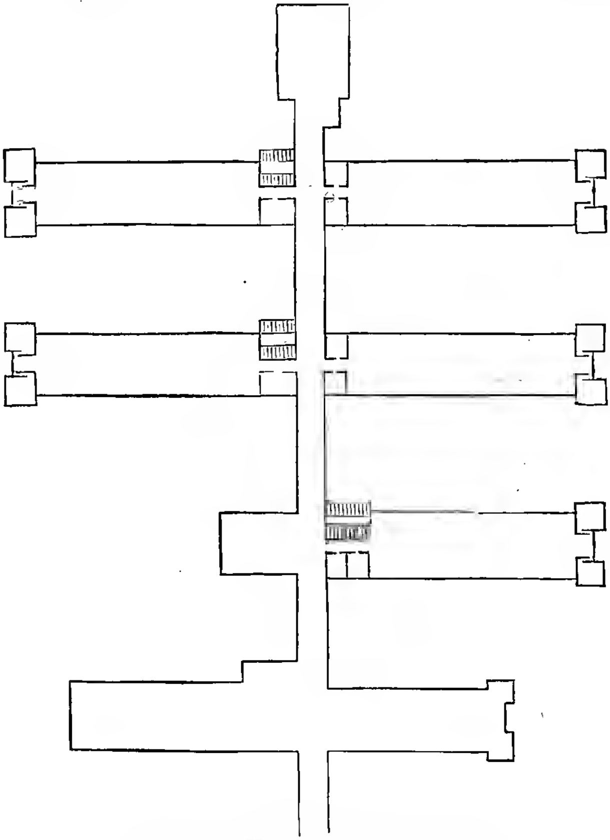
FIG. 14.—Herbert General Hospital.

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[1] Wylie: Hospitals, their History, Organization, and Construction, New York, 1877.

cumulate the foul air blown down the line at the last pavilion, and entire ventilation would only be secured with the wind nearly at right angles to the line. Among the plans submitted for the construction of a large hospital in Paris, after the burning of the Hôtel-Dieu, was one by Poyet, for 5,000 beds, in which the wards were arranged in radii of a circle. A committee of the Academy reported favorably in regard to the project, but it was not adopted. Such an arrangement, while affording great facilities for the administration of the hospital, is objectionable, as some of the pavilions must of necessity be placed at a wrong inclination to the sun and the prevailing winds. It should be a general rule that no angles or closed or covered courts are admissible in the general arrangement of the hospital. All such recesses are merely foci for foul air, and are to be strictly avoided. To illustrate this point, ground plans of the Royal Free Hospital, the London Hospital and Guy's Hospital, in England, and the Necker in Paris, are given; all of them show faulty arrangement.

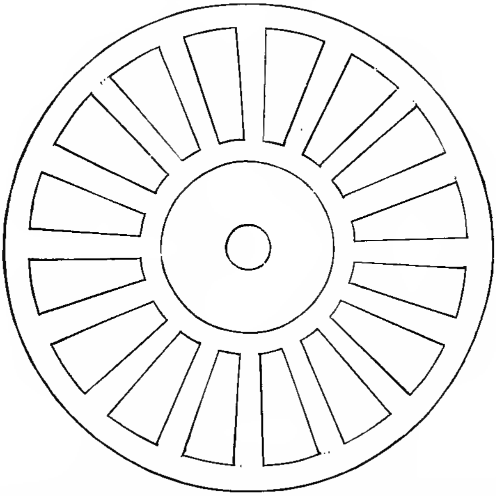

FIG. 15.—Poyet's plan of hospital, with wards arranged in radii of a circle.

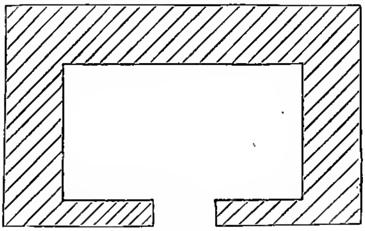

FIG. 16.—Royal Free Hospital.

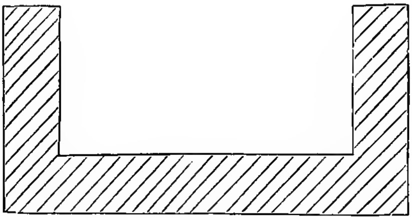

FIG. 17.—London Hospital.

Number of stories or floors.—The question whether wards shall at any time be superimposed on each other is an important one. The single

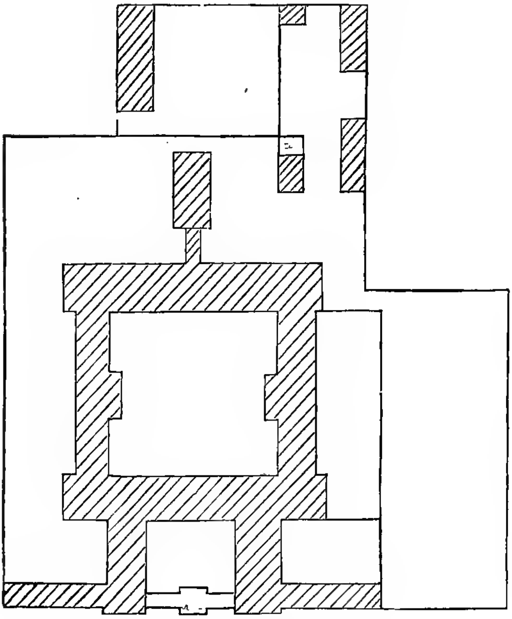

FIG. 18.—Necker Hospital.

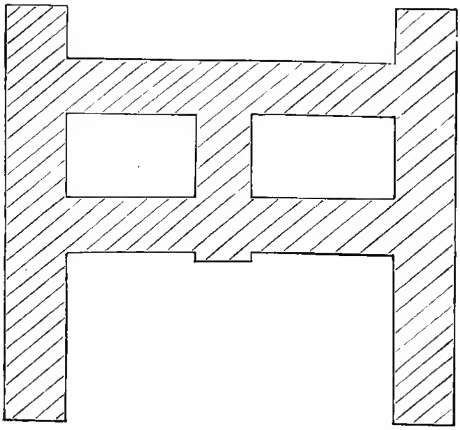

FIG. 19.—Guy's Hospital.

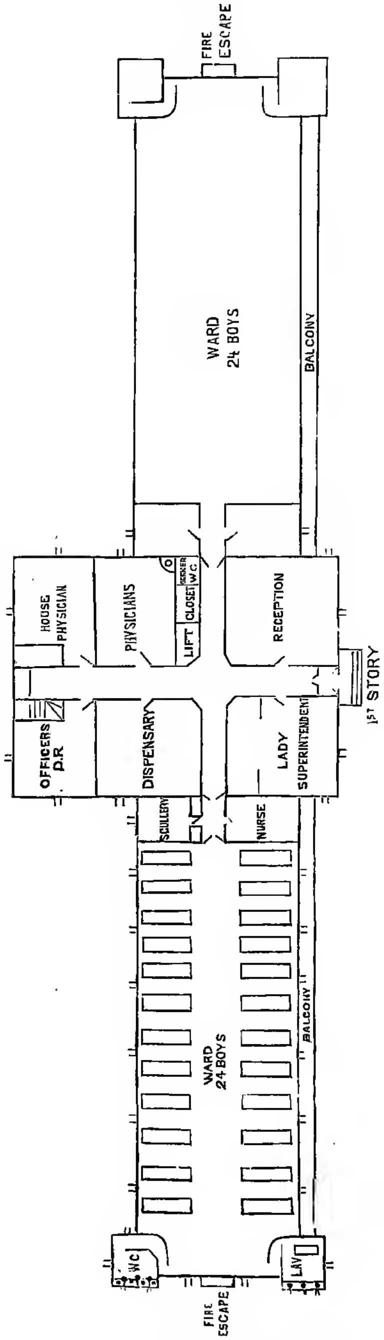

FIG. 20.—Plan of a hospital for children.

story is by far the best, where space allows. The one-story hospital is more easily managed: there are no stairways or elevators to be constructed, water-tanks and pumping-engines are unnecessary, and lighter foundations are required. For the uses of the general non-infecting cases of disease, two stories may be employed; for open wounds and diseases of a possibly or decidedly contagious character, the single story is decidedly preferable.

Dr. Wylie thus sums up his views upon the question under consideration: "The points in the argument for one-story wards may be summed up thus:

"1. Experience and science agree in showing that widely detached one-story wards allow the most thorough ventilation, and therefore the smallest chance for the accumulation of infectious particles.

"2. They neutralize the evils of massing large numbers of cases—or, what amounts to the same thing, varieties of cases, under one roof. They make classification of cases easy and natural.

"3. They require less vigilance; dust and foul air find fewer lurking-holes and channels; cleanliness and ease of supervision, as well as fresh air, are more readily secured. Two-story hospitals may be kept healthy for a few years with extreme care and intelligence. Hospitals of more than two stories ought never to be contemplated.

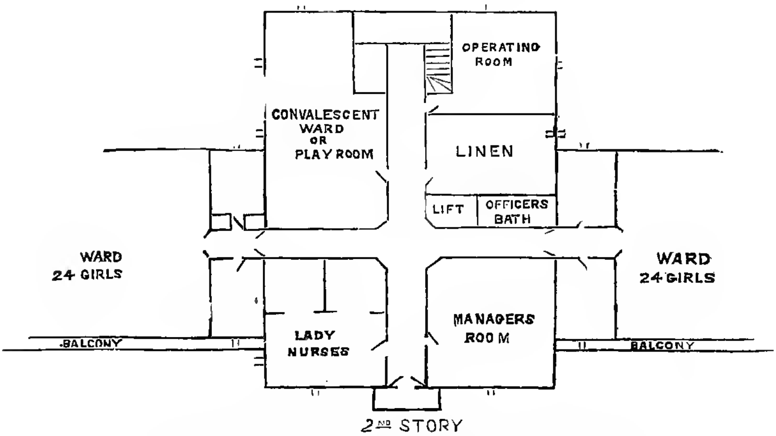

FIG. 21.—Second story of the same hospital (see Fig. 20).

(Drawn on a slightly larger scale.)

"4. The detached ward plan, which is hygienically the safest, is also the most economical, apart from the amount of land required. A ward hopelessly poisoned by long occupation, if detached, can be torn down without disturbing the general order; and when additional accommodation is necessary, other wards may be added one by one, or a short ward can be extended.

"5. An immense advantage of one-story wards . . . is the ease with which patients can be taken, bed and all, out of doors in fine weather.

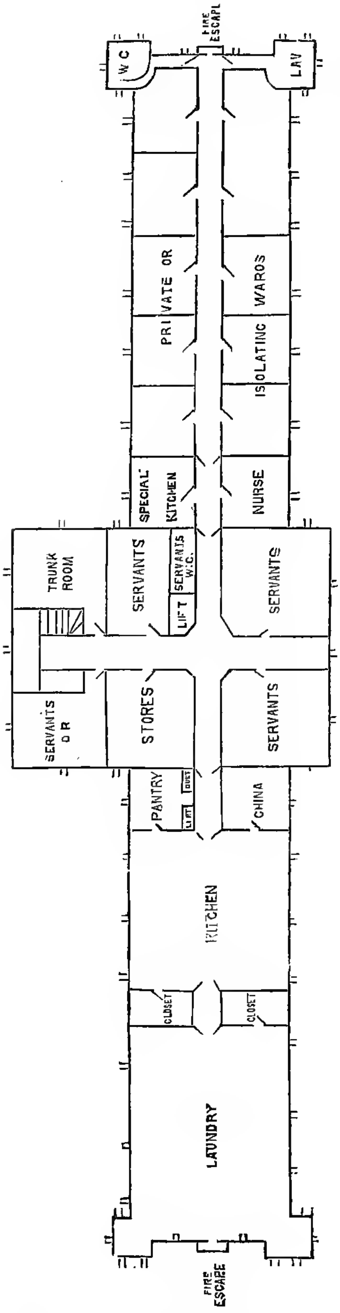

FIG. 22.—Third story of same hospital (see Fig. 20).

Even the very feeble can be wrapped in a blanket and rolled out on the grass by an incline, with no fatigue of 'getting ready.'"[1]

In the detached plan the administrative department, including the general offices of the establishment and those of the medical officers, the reception-rooms, drug-room, and other apartments which must be often visited, should be at or near the centre, for ease of access; the kitchen and laundry should be in a separate building, so situated as not to cause annoyance to the occupants of the wards by odors or smoke; the wards for private patients should be in a retired part of the grounds; the isolating wards or tents should be at a safe distance, and the mortuary or dead-house should be located at the outer edge of the grounds, at the rear. Where necessity requires the use of a single building for several wards, the plans designed for a children's hospital of ninety-six beds (Figures 20, 21, and 22) may serve as a good example of the proper disposition of the several parts. In such a building the administrative department should be in the centre, with the pavilion wards extending on each side. Where it seems unadvisable to place the kitchen and laundry in a separate building, an excellent plan would seem to be to locate it in the highest story.[2] In this way the odors of cooking and the more offensive and injurious effluvia from the washing and drying of clothes are avoided, and in addition the fires may be utilized as a powerful exhauster for the ventilating flues of the wards below.

Staircases.—In hospitals of more than one story the staircases should be

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[1] Wylie: Op. cit.

[2] This has been done, in the recently constructed buildings of the New York Hospital.

placed in a well, cut off from other parts of the building by stone or brick walls. Each pavilion should have its own staircase, and, in each building of considerable size, at least two would be called for. The rise of each stair should be not more than four inches and the tread one foot. Frequent landings allow feeble patients to rest, and the system by landings is easier to pass over than a constantly winding flight. The best material for the stairs would seem to be solid slate. This does not wear away and become uneven as sandstone or marble, or even granite is likely to do, and it does not polish and become slippery, as is apt to be the case with iron staircases. Fire-escapes should also be provided.

Elevators.—Elevators to carry patients up and down should be firmly constructed, provided with safety appliances, and enclosed, like the stairs, in fire-proof wells. That they may not be the means of communicating the air of one part of the building to another, the wells for the staircases and elevators should be separately and well ventilated.

Shoots for soiled clothing.—The question of shoots for soiled linen, dust and ashes has been proposed, and in like manner has met with opposition. If used they should be made of glazed pottery or large drain-pipes. They should open into the scullery or into the hall, and should be provided with well-fitting doors. It is essential that they should be continued to the roof, in order that they may receive perfect ventilation. They should be inspected daily, and frequently cleansed. It would perhaps be still better if they could be placed entirely outside the building, and be accessible on each story only by opening a window.

Corridors.—Closed corridors connecting the various buildings are undesirable. They not only constitute a means of obstruction to the air passing between the buildings, but serve to foster that opprobrium to many, if not most of our present hospitals, the dissemination of a common hospital air. As the patients are not obliged to pass from one pavilion to another, they will run no risk of exposure by open corridors, and the nurses and other officers can submit, without serious detriment, to the occasional inconvenience attendant on the weather.

In the discussion which followed the reading of Galton's Treatise on Hospital Construction before the British Medical Association, Dr. Rumsey, of Cheltenham, thus spoke of the disadvantages of covered corridors: "As showing the defect of the corridor system, he was informed by one of the professors that in a case of hepatic abscess, which contained highly fetid pus, and had been opened in a ward at the extreme end of the corridor, the first announcement that the horrible smell was perceived in the hospital, was made, loudly enough, from a ward at the other end of the corridor, a third of a mile distant, showing that the putrid air had been carried by the corridor to that distance."[1] It should be established as a rule that all corridors connecting the different parts of the hospital should be constructed without closed sides, or, in climates where the winters are severe, if closed, they should be very freely supplied with windows. These should be constantly open throughout the largest part

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[1] Galton: Op. cit.

of the year, by night and by day, and should only be closed during storms or in the very coldest weather. Where it is deemed necessary to have closed corridors they should be separated from the wards at each end by light, double-swing doors, covered with enamelled cloth or similar material, which, being constantly closed, will prevent draughts and the passage of hospital air. The corridors on either story may serve as exercise grounds for patients when the ground is wet or very cold, as well as a means of communication.

Balconies.—If the buildings are made of permanent materials, and of more than one story in height, well-supported balconies may be placed on the sunny side, to give patients the advantage of out-door air on a level with their wards. Awnings should be used to keep off the sun when too powerful. The balconies should be well guarded, to prevent delirious patients from throwing themselves off.

SECTION V.

ARRANGEMENT IN DETAIL.

The ward and its adjuncts.—We now come to the detailed arrangement of the ward and its adjuncts. The ward unit, which in itself constitutes a hospital, will be described, and the principles may be worked into hospitals of any character, whether of single or many pavilions, separate or joined together, in one or more stories. It should be remembered, however, that the nearer the plan is made to conform to the detached, one-story pavilion system, the better will be the result, and that *in no case* is the block or the corridor system to be adopted.

A plan of one of the wards of the Hôpital Lariboissière, in Paris, is given for reference. (Fig. 23.)

Size of ward.—The wards in the Lariboissière Hospital, which accommodate 32 patients each, are of the following dimensions: length, 111.6 feet; breadth, 30 feet; height, 17 feet; breadth of windows, 4.8 feet; breadth of wall-space between windows, 9.2 feet; height of windows, 13 feet; superficial space per bed, 104.6 feet. Simon[1] gives thirty feet as the desired width, and Miss Nightingale[2] twenty-five or twenty-six. Parkes[3] and Uytterhoeven[4] give not more than twenty feet. In the Herbert Hospital the width of the ward is twenty-six feet, in the new St. Thomas's Hospital twenty-eight, and in the new Hôtel-Dieu twenty-

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[1] Simon: Reports on Public Health, London, 1863.

[2] Nightingale: Notes on Hospitals, London, 1863.

[3] Parkes: Practical Hygiene, London, 1869.

[4] Uytterhoeven: Notice sur l'Hôpital St. Jean à Bruxelles, 1852.

nine feet. A greater width than thirty feet has been found to interfere with a due system of ventilation, and a width of less than twenty-four feet gives insufficient space for two rows of beds. The width of the ward may best be put at twenty-four or twenty-five feet. The beds may be set one foot from the wall, which makes it easy to approach them from all sides, and conduces both to cleanliness and to efficient ventilation. If the beds are six and a half feet in length, this will give a clear passage between them of nine or ten feet.

Superficial and cubic space per patient.—It may be given as a general rule that a medical ward for twenty patients should be, at the smallest, of the following dimensions: length, 80 feet; width, 25 feet; and height from 16 to 20 feet. Each patient would then have about 100 superficial and 1,600 cubic feet of space. For surgical wards the number of patients in the ward should be smaller. Sixteen patients in the same space would have each 2,000 cubic feet, and where such a room is used as an isolating or foul ward, not more than ten patients should be accommodated, which would give to each 3,000 cubic feet.

The subject of superficial and cubic space to be allotted each patient has been freely discussed in works on hospital construction. The following table exhibits the superficial area in certain new hospitals in England and France:

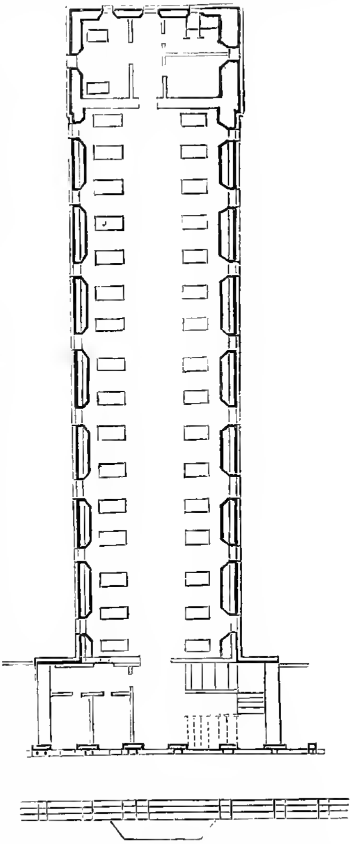

FIG. 23.—Lariboisière Hospital.

Naval Hospital........	98 feet.	Guy's...............	138 feet.
Herbert..............	99 "	New Hôtel-Dieu, 104 to	110 "
Royal Victoria (Netley)	103 "	New St. Thomas's.....	112 "

In English hospitals the cubic space varies from 600 to 2,000 feet; in London from 2,000 to 2,500 is considered advisable; and in Paris 1,700 has been adopted as the standard.[1]

Number of patients in a ward.—The number of patients in a ward and the cubic and superficial space to be allotted to each are, to a certain extent, convertible terms. Miss Nightingale says: "A head nurse can efficiently supervise, a night nurse can carefully watch, thirty-two patients

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[1] Martin: Holmes's System of Surgery, London, 1862.

in one ward, whereas, with thirty-two beds in four wards, this is impossible."[1] M. Trélat would reduce the standard to a lower number—from fifteen to twenty—and his opinion was endorsed by the Surgical Society of Paris.[2] "In wards of nine sick, managed like those at Netley, the cost of efficient nursing would be nearly twice the cost of efficient nursing in wards for thirty-two beds on the Lariboissière plan."[3] Hennen says: "I should, for the majority of purposes, prefer wards capable of accommodating from twelve to sixteen beds."[4] Pozzi fixes the maximum at forty.[5] On the score of expense, Miss Nightingale shows that, if the annual cost of nursing be capitalized, and if a hospital for a given number of sick be divided into wards of nine patients each, the cost of nursing in perpetuity would be £428 per bed; whereas, if the hospital were divided into wards of twenty-five beds each, the cost would be £231 per bed; and with wards of thirty-two beds each, the cost would be £220 per bed.[6] To recapitulate: from twenty to thirty-two beds in a ward seems to be the most desirable limit for ease and economy of administration and for facility of ventilation. Each bed should have not less than one hundred feet of superficial space, and from fifteen hundred to twenty-five hundred feet of cubic space.

Fallow wards.—Some of the faults of hospitals already constructed, such as those arising from insufficient space, poor means of ventilation, all those errors incident to the block and corridor systems, may, to a certain extent, be overcome by following the plan in vogue in many hospitals, of allowing alternate weeks of use and disuse. The custom of allowing the wards thus to lie fallow for definite periods necessitates larger accommodations, but it is largely compensated for by increased health in the hospital. Were the wards merely used, as are the bed-rooms of private dwellings, as night-rooms, we might say that the airing they receive each morning would suffice; but as they are necessarily both day and night abodes for the sick, there is no other way in which a thorough airing can be accomplished.

Windows.—The windows of the pavilion ward should be so arranged as to allow one to every two beds. The beds between the windows should be not less than three feet distant from each other, and the distance from the end of the ward not less than four feet and six inches. The windows should extend from two feet from the floor to within a foot of the ceiling; they should open easily at top and bottom, should have sills of slate or marble, and should be suitably arranged for purposes of ventilation, as will be described on a later page. At least one window in each ward should open like a door, to give access to the balcony. One superficial foot of window to from fifty to fifty-five cubic feet of space will afford a light and cheerful room in most climates.

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[1] Nightingale: Appendix to Report on Cubic Space, London, 1867.

[2] Trélat: Les Hôpitaux, etc., Paris, 1866.

[3] Report of Committee on Barracks and Hospitals, London, 1861.

[4] Hennen: Op. cit.

[5] Pozzi: Polizia degli Spedali, Livorno, 1839.

[6] Nightingale: Notes on Hospitals.

Square wards vs. long.—In contradistinction to the long pavilion wards, those more nearly square in form have been adopted at the Massachusetts General and other hospitals, apparently with good results. Dr. Folsom recommends that such wards should be 56 by 43 feet, these

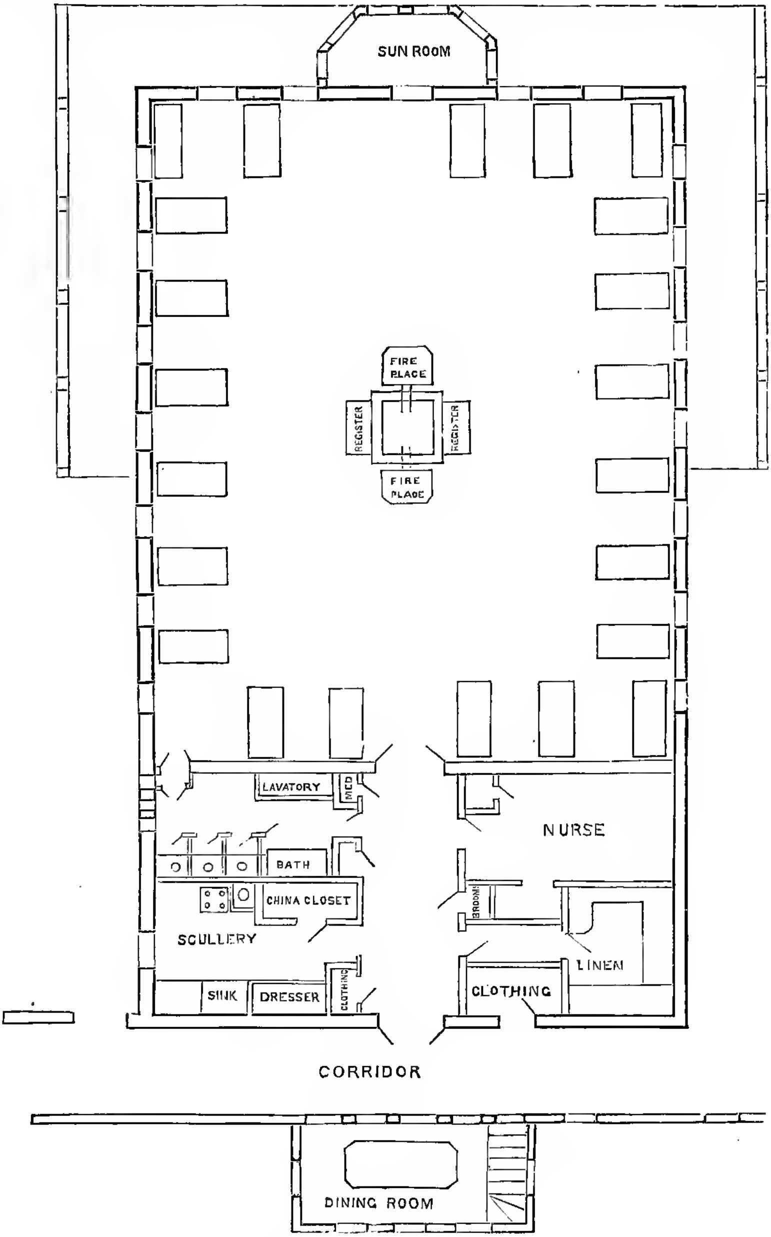

FIG. 24.—Folsom's plan.

dimensions being calculated for 23 patients. A central chimney and ventilating stack occupies the middle of the ward, is provided with open fireplaces and registers, and affords abundant means for ventilation. He says: "The advantages of a nearly square room with a central stack are: the privacy of each bed, as compared with its situation in a long hall without obstruction to the view; the absence of draughts, the fireplaces and warm-air supply being nearly equally distant from all parts of the ward, and the chimney stack, by its volume and position, interrupting and mixing accidental air-currents; and the ease of administration, the beds being nearly equidistant from the supplementary rooms of the ward."[1]

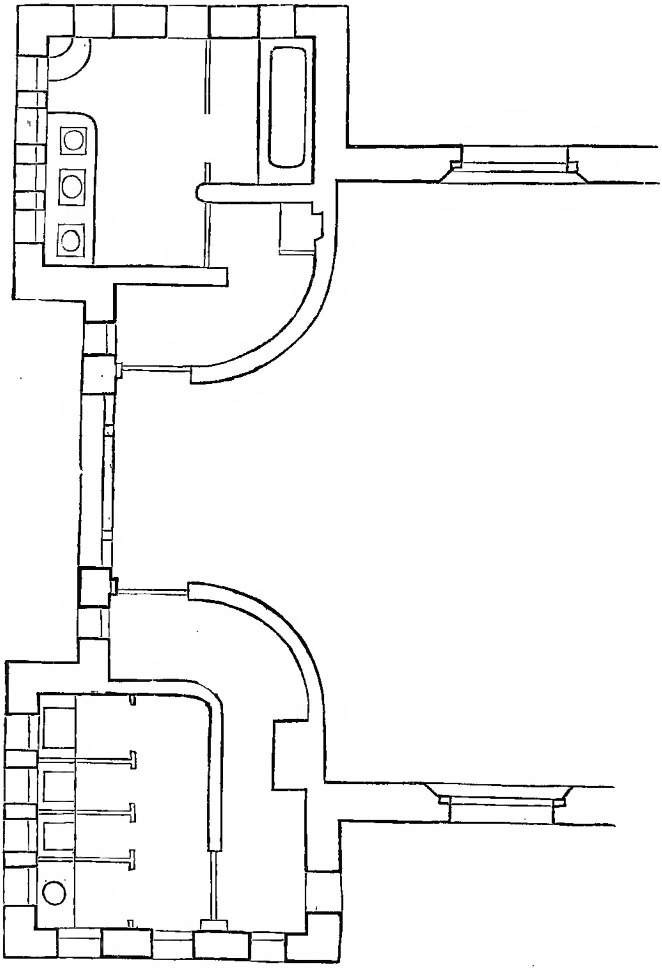

FIG. 25.—Miss Nightingale's plan for the water-closets and lavatory.

The great objections to the plan proposed by Dr. Folsom seem to be

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[1] Plans for Johns Hopkins Hospital.

the too close proximity of the water-closets to the wards; that the sunlight does not so completely reach all parts of the ward in the square form as in the pavilion proper; and that the entire ward cannot be so fully under the supervision of the nurse. The sun-room or glazed porch is, however, a very desirable feature, and can be more advantageously attached to the square than to the long ward.

Ward adjuncts.—The adjuncts of the ward are the water-closets and urinal, the lavatory, nurse-room, scullery, dining-room, clothes and medicine closets, and sun-room. The *water-closets* should be in a room at the distal end of the ward, and this room should be separated from it by ventilated lobbies, and should be itself well ventilated. The disposition of the closets given by Miss Nightingale [1] is a very good one, but perhaps that given by Galton[2] is better, as the diagonal position of the connecting lobby is more adapted to catch the currents of air passing along the side or end of the building, and so secure more efficient ventilation. The walls should be

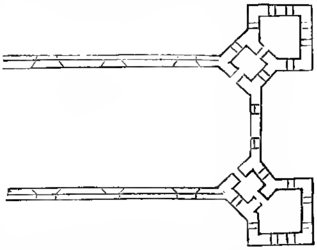

FIG. 26.—Galton's plan for the disposition of the water-closets.

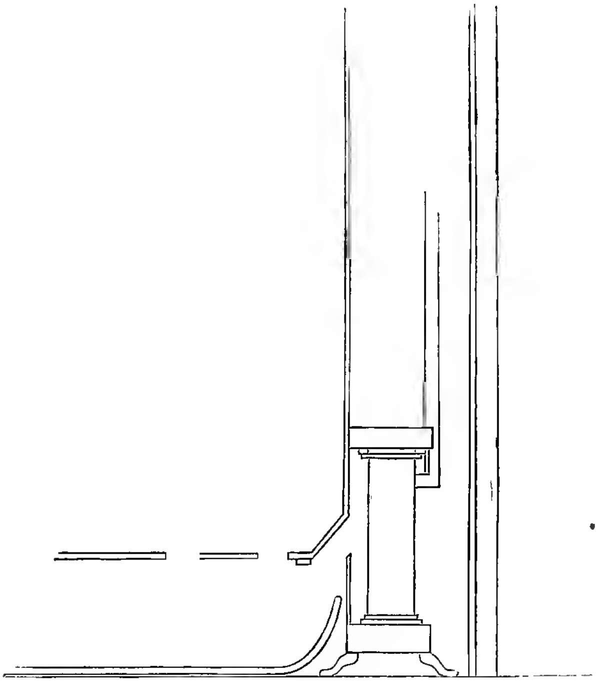

FIG. 27.—Plan of separate ventilation for water-closets.

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[1] Nightingale: Notes.

[2] Galton: Op. cit.

set with solid slabs of glass, slate, or marble, to a height of at least seven feet from the floor, and partitions of slate or marble should separate the closets and urinals. Each closet should be provided with doors of ash, having self-closing hinges, and with a wooden seat on hinges, and it should have no other casing. The entire plumbing and accessory framework of the closet should be left exposed, for the sake of cleanliness and ease of repair. The floors should be of slabs of slate or marble, to allow the free use of water by a hose. A simple means of separate ventilation for the water-closet is shown in Figure 27.

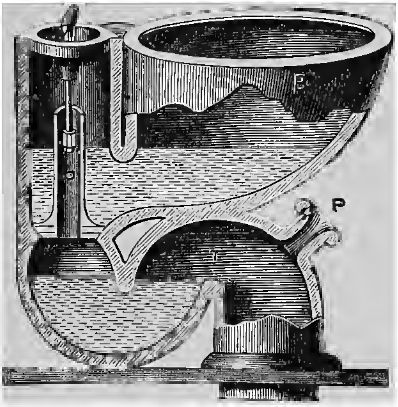

Fig. 28.—Jennings' all-earthen closet.

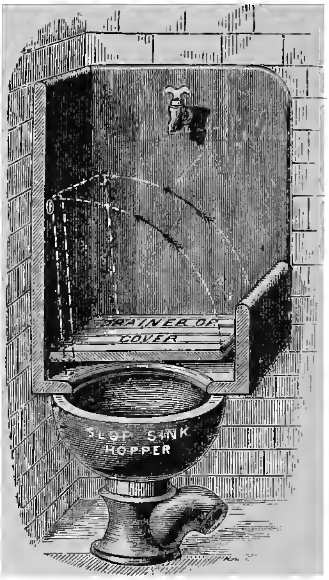

Fig. 29.—Sink for slops.

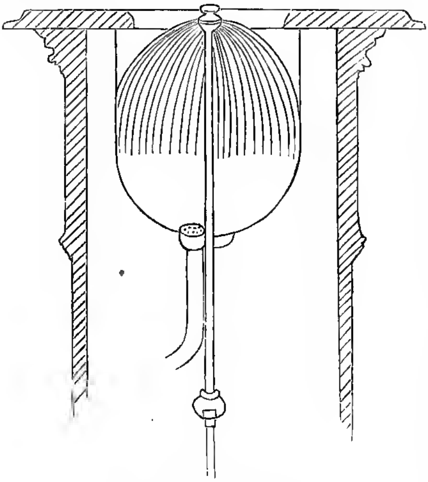

Fig. 30.—Spray urinal.

At least a hundred patterns of water-closets have been brought before the public. One of the simplest and that requiring the least care is known as the Jennings all-earthen closet, and this has been adopted in many of the hospitals of the day. Provision should not only be made for ventilating the seat of the closet, but a ventilating tube should also extend from the trap (T) to a shaft above. The vent (P) is provided in the Jennings closet for this purpose. One water-closet should be provided for every ten patients. A sink should be provided in the same apartment for the disposal of slops and the contents of chamber-vessels (Fig. 29). It should be supplied with a large tap for water. An excellent form of urinal is one in which a thin spray or sheet of water is thrown out from a jet to the sides of the basin, forming a complete veil through which the urine is projected into the vessel (Fig. 30). This plan has recently been patented, and has been used in some of the public urinals.

The question may arise whether independent water-closets or privies, outside the building, may not be serviceable for those patients who are able to be in the open air. If it be thought desirable to have such privies, they should be placed at a proper distance from the wards and screened from the public view. The question of external water-closets must, of course, depend on the ability of patients to leave their beds, and still more, to ascend and descend stairs. The following census of the patients at Bellevue Hospital, New York, with reference to their ability to traverse a flight of stairs, was recently taken:

Number able to traverse a flight of stairs	242
" " walk only about the ward	101
" unable to leave their beds	99
Total	442

These figures cannot, however, be safely taken as a criterion to determine the advisability of removing the water-closets from the wards. The exposure to cold, the difficulty of deciding who could or who could not go into the open air, and other considerations, would lead one to dissent from Dr. Smith's views in this respect, as well as from his suggestion of "the small room on the ward floor, with dry-earth closets, a urinal, and a lavatory,"[1] with which easy mention he dismisses the subject of water-closets.

Lavatory.—The lavatory and bath-room may, in like manner, be situated at the distal end of the ward. This room should be furnished with set basins, for hot and cold water, in the proportion of one for every eight patients, and be well warmed and ventilated. A suitable plan is that given by Miss Nightingale in Fig. 25. The floor should be impervious to water, and all plumbing should be exposed. Fixed bath-tubs, in separate rooms, adjoining the lavatory, should be allotted in the proportion of at least one to every twenty patients. A movable tub, mounted on wheels, must be supplied, for the use of patients who are unable to leave the wards.

The remaining service-rooms of the ward may, in the long wards, be at the proximal extremity, or that nearest the general administrative department.

Nurse-room.—The nurse-room should be light, cheerful, and well-aired. As it is not only the office of the head nurse of the ward for the transaction of the regular ward business, but her living and sleeping-room

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[1] Johns Hopkins Hospital Plans.

after her work is over, it should be on the sunny side of the ward and be comfortably arranged. It should have a door opening into the hall, and a window, for the supervision of the ward, opening into it. The under-nurses and night-nurses should have rooms in other parts of the hospital.

Scullery.—The scullery or work-room should be near the room of the nurse and under her eye; it should be supplied with a small range or a gas-stove for the cooking of special diets and delicacies; an enameled sink with hot and cold water; closets for the crockery of the ward dining-room, and for brooms, brushes, and similar utensils to be used in cleaning. It should be carefully ventilated. The under-nurses might take their meals there.

Dining-room.—A small dining-room, annexed to each ward, is very desirable for such patients as are able to be out of bed, in order that they may be removed, during meal-times, from sights and sounds which influence the appetite of a sick person.

Medicine, linen, and clothes closets.—Closets for the medicines, linen, and utensils in actual use in the ward should open from the hall. In addition a large, separately ventilated closet should be provided, with at least one window, and ranges of shelves or pigeon-holes, about eighteen inches high and two feet deep, to hold the clothing not needed by the patients in the wards. If made of wire netting, with coarse meshes, the shelves will be more satisfactorily ventilated and more easily kept clean.

Sun-bath.—All hospitals, of whatever form of construction, should have rooms where a sun-bath can be enjoyed at seasons when exposure to the outside air would be prejudicial to delicate persons. They should be immediately contiguous to the wards, have glazed windows on three sides, and be furnished with comfortable chairs and lounges.

Convalescent wards.—If the patients remain in the hospital until convalescence is thoroughly established, it would be well to have separate wards provided for their convenience. Such patients will more quickly reach a condition of perfect health, in the intermediate stage between hospital and home, if a change of scene be allowed them, and if they are removed from the presence of their more seriously sick companions. Such accommodations should be arranged with a due observance of the needs of sunlight and ventilation; they should have separate dining- and sitting-rooms, and be surrounded with grounds for exercise and amusement.

Convalescent branches.—Some of our hospitals are already provided with convalescent departments in the country, or are supplemented by other institutions, at a distance, to which patients can be removed when convalescent. The Convalescent Home of the Ormond Street Hospital in London, the Seashore Home for Children, at Atlantic City, N. J., and the Convalescent Home of The Children's Hospital, in Boston, are examples of this wise provision.

Private wards.—A certain number of private wards are desirable in every hospital for patients of the higher classes, who, from insufficient home accommodations or other reasons, may seek the hospital. Certain advantages, such as retirement, separate attendance, etc., which are generally enjoyed by persons of refinement and culture, will largely conduce to their recovery and welfare. Private wards should be of a size to accommodate one, or at most, two beds, and a certain number of them should have connecting-doors for the convenience of friends or private nurses; separate water-closets and bath-rooms and open fireplaces should be provided for each room.

Isolating wards.—In all hospitals there should be set apart for contagious cases certain rooms, capable of the best ventilation, and with abundant light, which can be separated from all surroundings. Notwithstanding Miss Nightingale's statement that, "in the ordinary sense of the word, there is no proof such as would be admitted in any scientific inquiry, that there is any such thing as contagion," and, in speaking of infectious diseases, that "in reality there ought to be no disease so considered; and, with proper sanitary precautions, diseases reported to be most infectious may be treated in wards among other sick without danger,"[1] public opinion would demand that no risk should be run in such cases. Patients suffering from contagious or infectious diseases, or foul wounds, delirious patients, and those otherwise disagreeable to the senses of sight, hearing, or smell, must be treated apart. Ovariotomy cases must be occasionally operated on in general hospitals, but their treatment should be regulated with great care. Isolating wards should be carefully separated from other parts of the hospital; in large hospitals they should be located in distant parts of the grounds, and in the smaller ones, in the upper story, where they should be cut off by double doors, with separate entrances, if possible, and separate and abundant ventilation. Such a ward should be built with separate rooms to accommodate one, or at most, two in each room. The administration of these wards necessitates separate nurses and attendants, and medical officers should visit them last in their daily rounds. The special isolated hut, so fully described by Dr. Wylie, of New York, in his work on Hospitals, meets the case excellently.[2]

One or two of the rooms of the isolating ward might be made close rooms or cells, for the accommodation of cases of delirium tremens, or for patients who have become suddenly insane.

Tents.—The more nearly patients are brought to the condition of being treated in the open air, the more quickly and surely will they recover. The wooden barrack and the hut are good, but for many cases the tent is better. As adjuncts, at least, to the hospital, we should look to the tents in our hospital yards, in the warmer season, as the most suitable places in which to treat the gravest wounds and many of the severer forms of disease. "Ever since 1864 the Surgical Clinic of the Bethanien Hospital in Berlin has been removed through the summer to tents in the garden of the establishment. La Charité, in Berlin, following the example of the Russian hospitals, constructed a summer pavilion. In 1866, Stro-

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[1] Nightingale: Notes on Hospitals.

[2] Wylie: Op. cit.

meyer treated the wounded of Langensalza in tents, and at this day the tent and hospital barracks are used during the summer at Berlin, Vienna, Leipzig, Dresden, Frankfort, etc."[1]

The tent offers to the smaller towns a ready means for the care of small-pox, typhus fever, and similar contagious diseases, and whether cottage hospitals be provided or not, the addition of a tent or two will, at some time or other, be found useful. "It must readily be seen how easy and simple a thing it is to provide good hospital accommodations in any emergency—no matter how sudden and unexpected—that the prevalence of epidemic and infectious diseases may occasion."[2]

Dr. Billings recommends that, for a hospital of 400 patients, fifteen hospital tents of the U. S. A. pattern be kept constantly on hand, and made methodical use of as isolated wards.[3]

Administrative department.—The general administrative department of the hospital, if of considerable size, will comprise the office of the institution, reception- and waiting-rooms, apartments for the visiting medical staff and house officers, rooms for the matron and other employés, for the storage and dispensing of medicines, linen, and stores, a chapel and library, all of which might be in one building, which should be centrally located on the front line of the hospital. The construction of this building requires no special description.

The resident physician or executive officer should be provided with a cottage on the grounds, for himself and family. The plan of furnishing him with quarters within the hospital buildings is undesirable.

Accident and operating rooms.—The accident and operating rooms should be in a separate building, centrally situated, and easy of access, and but one story in height. The operating amphitheatre should be provided with seats for the accommodation of physicians and students who desire to witness the operations; it should be fully lighted by large windows opening toward the north; full provision should be made for ventilation, and gaslights for use at night should be placed at a considerable distance from the operating-table, in order to avoid accidents from the ether catching fire. Instrument- and apparatus-rooms should adjoin the two rooms. A room for the administration of anæsthetics, a small ward for patients who are waiting for or recovering from operations, and consulting-rooms for the medical officers, are also required.

Kitchen and laundry.—In large hospitals the kitchen and laundry, with pantry, store-rooms, refrigerators, etc., should be placed in a central position, but in a building which has no connection whatever with the wards, either by corridors or in any other manner. In smaller hospitals, where the entire establishment is under one roof, it is decidedly preferable that they should be situated in the upper story, with suitable and well-ventilated lifts from the lowest story, for carrying up coal and stores, and

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[1] Le Fort: La chirurgie militaire, Paris, 1872.

[2] Cowles: Treatment of the Sick in Tents and Temporary Hospitals, Boston, 1874.

[3] Johns Hopkins Hospital Plans.

for the conveyance of food and linen to the wards. All these lifts should be carried above the roof, where they should end in ventilators. The kitchen and laundry should never be in the basement. These apartments should be separated from other parts of the building by double doors and ventilated lobbies, and they should also receive abundant ventilation by direct communication with the open air. Coal and the heaviest stores, and the boilers, may be in that portion of the basement which is situated beneath the administrative department; but, as previously stated, that part of the basement below the wards should be reserved exclusively for ventilating and heating purposes.

A room for the purifying and disinfecting of mattresses and linen may be situated near the laundry, with racks for support, and means for filling the room with steam and disinfecting gases.

Autopsy- and dead-room.—The autopsy-room and mortuary should be at some distant part of the establishment, where they can be easily reached by friends from the outside, and from which bodies can be conveyed without being seen by patients in the wards. The floors and mop-boards of this building should be of slate, and the walls painted. The autopsy-table should be ventilated by a separate apparatus. The excellent pattern suggested by Dr. H. J. Bigelow, and figured in the book published by the trustees of the Johns Hopkins Hospital, leaves nothing to be desired in this direction. A limited number of seats should be provided for students who desire to witness post-mortem examinations. Hot and cold water should be supplied.

The mortuary or dead-room should adjoin the autopsy-room, as should rooms for the use of the pathologist and for the pathological cabinet.

Out-patient department.—Rooms for the treatment of out-patients, with small rooms adjoining for attending physicians and surgeons, are usually required in large hospitals.

The necessity for ambulances in connection with every large hospital is well recognized. If ambulances are used, provision must be made for a stable, with apartments adjoining for medical officer and driver, and telegraphic communication.

SECTION VI.

MEANS OF HEATING.

The subject of heating and that of ventilation are largely dependent on each other. A satisfactory system of ventilation implies the extraction of a large amount of warm air, and necessitates the heating of a corresponding amount of air to take its place. Cheap heating implies poor ventilation. The managers of a hospital must therefore be content, if they desire an efficient method of ventilation—in itself the great safeguard of the patients—to supply large means of heating.

In most cities and towns in the temperate regions the thermometer ranges through the year from zero to one hundred degrees of the Fahrenheit thermometer. In the latitude of Boston artificial heat must be supplied, to a greater or less extent, for six or seven months in the year, and at all seasons occasional cool mornings and evenings call for moderate fires.

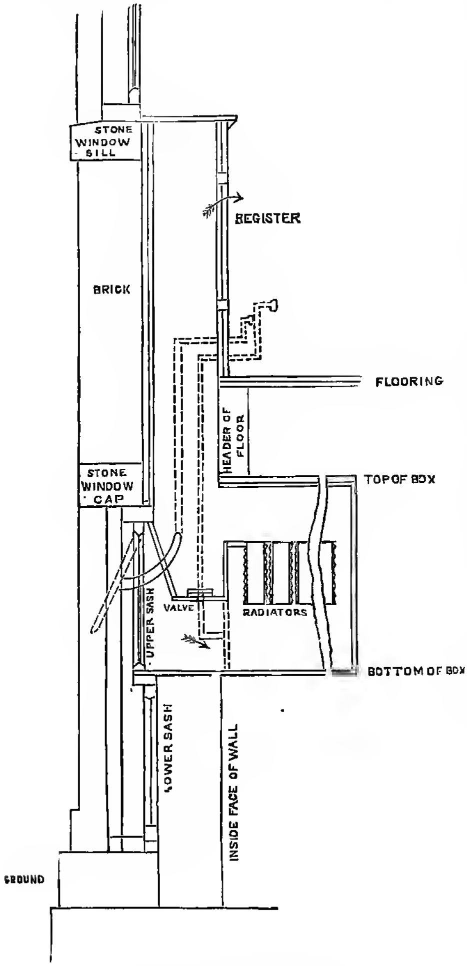

FIG. 31.—Folsom's radiator.

Heat may be furnished either by hot-air furnaces, by steam- or hot-water pipes and radiators, or by open fireplaces or ventilating stoves. Furnaces are less easy to manage in large institutions; the currents of hot air, if conducted for considerable distances, are uncertain and are easily affected by varying winds and changes in the temperature. Heat from hot-water pipes is mild and agreeable, but is not so prompt in its action as heat derived from steam-pipes; the hot-water pipe system, furthermore, is ill adapted to climates where sudden changes occur in the temperature. Heat derived from steam-pipes is more generally used. This may be derived from coils of pipes which are placed in chambers in the basement, and from which the hot air is conducted as from hot-air furnaces, and distributed to the wards. The same intractability is apparent here as with heat derived from furnaces. The best method seems to be that of placing coils or radiators immediately under the rooms to be heated, with openings communicating with the outside air, from which fresh air may pass over the coils and be then conveyed directly into the wards or rooms. By this division of the coils the heat is more generally distributed, it can be more easily kept under control, and the air is more economically warmed.

Dr. Folsom, in the "Plans for the Johns Hopkins Hospital," thus describes his method of regulating the temperature of the air to be admitted into the wards:

"The radiators are hung from the floor-timbers by iron rods, and are enclosed in a wooden box lined with tinned sheet-iron, with a door at the side for the removal of dust.

"The air is admitted through the top half of the cellar window, which is hung on hinges at the top, and opens outward, and the amount of air admitted is regulated by a crank in the room above, which connects by a rod, with a quarter circle attached to the window-sash. The movement of the crank opens and closes the window; but opening to the full extent, represented by dotted lines in the plate, would be desirable at all times, unless during a very high wind.

"The direction of the air thus admitted is determined by a valve made of a strip of board suspended by hinges from below the front of the radiators, the position of which is regulated by a rod connected with a second crank in the room above. The stability of the crank in the position given it by the hand of the attendant is insured by a set-screw, with a bit of rubber or leather beneath the tip.

"When the valve is in the horizontal position, all the air is directed to the radiators, and is fully heated by rising through the stack, after which it passes up through the space in the wall, beneath the window, to the vertical register just under the window-seat. When the valve is placed in the vertical position, indicated by dotted lines in the plate, all the air is directed upward away from the radiators, but is tempered by mingling somewhat with the air circulating in the space over the radiators, and then reaches the room by the register above. When the valve is placed in an intermediate position, the air-current is divided, part of it only is heated by passing through the radiators, and this then mingles with the ascending cold portion before it reaches the register and enters the room.

"It is apparent that the temperature of the room can thus be regulated to suit varying conditions, without interfering with the fresh air supply, and without modifying the access of steam to the radiators. If the room gets too warm, the nurse, instead of *closing the register*, and so shutting off the oxygen, simply turns the crank a little upward. If the thermometer, which hangs near the door, falls below the standard directed by the attending officer, the crank is turned downward. If a sudden general atmospheric change has taken place, and the temperature still falls, the *supply* of air may need to be temporarily diminished, till the engineer, who watches the thermometer out of doors as well as his gauges, has time to restore the suddenly fallen steam-pressure.

"The proper use of the contrivances described requires intelligence and faithfulness on the part of the attendant, but *no more* than would be required to properly regulate temperature in any other way."

In addition to the means of heating already mentioned, open fireplaces should be used in every ward, less for the purpose of heating than as an aid to ventilation, and for the moral effect on the patients. The fireplaces may be at the side of the long wards, and midway of their length, or in the centre. In the latter case the products of combustion must be conducted under the floor of the wards, and thence into side flues in the walls. In the square wards such means of heating are necessarily thrown into the centre of the wards, with the smoke-stack in the centre shaft.

The smoke-flues from all local fireplaces, and from all heating, cooking, or laundry fires, should be made of iron piping, or of earthenware, and be enclosed in ventilating flues ; no opportunity should be lost of securing so powerful an aid of ventilation as is furnished by this method.

SECTION VIII.

VENTILATION.

Various attempts have been made to settle scientifically the amount of air needed for satisfactory respiration. Experimenters have started from various standpoints, have adopted various methods, and, very naturally, have arrived at widely different results. The atmosphere outside of houses provides an unlimited extent of respirable air, and constant means of purification and movement. The erection of buildings continually interferes with natural conditions, by enclosing the air in confined spaces, saturating it with impurities, and rendering it stagnant. In the ventilation of hospitals the primary object should be to overcome this stagnation " with a continuous current which shall always be bearing away, as rapidly as evolved, every volatile taint which arises from the sick." [1] An adult man inspires and expires about thirty cubic inches of air at every respiration, and breathes about twenty times in a minute. With figures nearly akin to these, and making due allowance for the excretion of carbonic acid and watery vapor, and for the exhalations of the skin, Parkes concludes that the amount of air necessary per hour for a man in health must be about 2,082 cubic feet.[2] Pettenkofer, by a similar experiment, has fixed the amount at 2,120 cubic feet. [3] Grassi would make it 2,118 feet, and the experiments of Vierordt and Valentin reach similar results. Parkes says : " From a number of experiments in which the outflow of air was measured and the carbonic acid simultaneously determined, I have found at least 2,000 cubic feet per hour must be given to keep the carbonic acid at .5 or .6 per 1,000 volumes, and to entirely remove the fetid smell of organic matter. When 1,200 or 1,400 feet only were given, the carbonic acid amounted to .7, .8, or .9 per 1,000 volumes. My friend, Dr. Sankey, from careful experiments with a fan, found that when, in a ward in the London Fever Hospital used as a chapel, 800

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[1] Bristowe and Holmes : Op. cit.

[2] Parkes : Op. cit.

[3] Pettenkofer : Ueber den Luftwechsel, München, 1858.

cubic feet per head per hour were supplied, the ventilation was insufficient."

The committee on improving barracks and hospitals, after careful and long-continued investigations, arrived at the conclusion that 1,200 feet should be supplied to each man in barracks per hour, giving him at the same time 600 cubic feet of air-space.[2] Dr. Billings says: "It appears to me that 2,000 cubic feet per hour per man may be accepted as a proper allowance for soldiers in barracks."[3] The allowance required by the Metropolitan Board of Health of New York is 1,000 feet for each person inhabiting tenement-houses.[4] The medical regulations of the British army require the following cubic space for each man, proper means being taken that the air should be changed at stated times:

In permanent barracks	600	cubic feet.
" wooden huts	400	" "
" hospital wards at home	1,200	" "
" in the tropics	1,500	" "
" wooden hospitals at home	600	" "

At present the demands for ventilation in France, per hour, per person, are:

In hospitals for ordinary cases	2,120–2,470	cubic feet.
" " " wounded	3,530	" "
" " " epidemics	5,300	" "
" prisons	1,466	" "
" workshops, ordinary	2,120	" "
" " unhealthy	3,530	" "
" barracks, day	1,060	" "
" " night	1,410	" "
" theatres	1,410–1,765[5]	" "

Dr. Wylie says, in his work on hospital construction: "About 1,800 cubic feet of air-space, with a surface area of 124 square feet, has been adopted as the space required. We would have the space vary in accordance with the class of disease to be treated in the bed."[6]

Natural and artificial ventilation.—Ventilation is effected by two methods, somewhat indefinitely described as natural and artificial, the former being governed simply by the forces continually existing in nature, the latter by the forces set in action by man. Reid speaks of the natural method of ventilation as "a process by which the movements are induced or sustained in the air in the same manner as wind is produced in the ex-

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[1] Parkes: Op. cit.

[2] Report of Committee, op. cit.

[3] Johns Hopkins Hospital Plans.

[4] Code of Health Ordinance, etc., New York, 1866.

[5] Pettenkofer: Loc. cit.

[6] Wylie: Op. cit.

ternal atmosphere, these movements being increased, when necessary, by the action of heat, and by the erection of a shaft or chimney, that the heat may acquire additional force."[1] The indefiniteness of the subject is evidenced by the sentence quoted, as the latter part of the sentence distinctly encroaches on the methods more commonly known as artificial. A more decided division would be into methods by perflation (or the strictly natural methods), by aspiration or extraction, and by propulsion or injection, the last two being more commonly known as the vacuum and plenum methods of ventilation.

The method by *perflation* includes windows, fireplaces, and direct openings through the walls or the roof, including the so-called ridge ventilation. It has been previously stated that satisfactory ventilation depends to a certain extent on the dimensions of the room, and that a greater width than thirty feet is a hinderance to the passage of the air. An exceedingly high room is equally unsatisfactory, and, in one unduly lengthened, the air is likely to be pure at one end and foul at the other. It has also been found that a room with an arched or vaulted ceiling is more easily ventilated than one where it is flat.

Ventilation by windows.—The simplest mode of securing natural ventilation is by means of windows. In most seasons of the year these can be opened for at least part of the day, and if raised at the bottom one inch and lowered at the top an equal amount, excellent ventilation can be secured with little danger of draught. The perforated glasses secure a certain amount of air. The method suggested by Dr. Cotting, of raising the lower sash about three inches, and inserting a board the width of the window, secures a considerable ventilating space between the two sashes at their point of junction. The adaptation of boards at the top and bot-

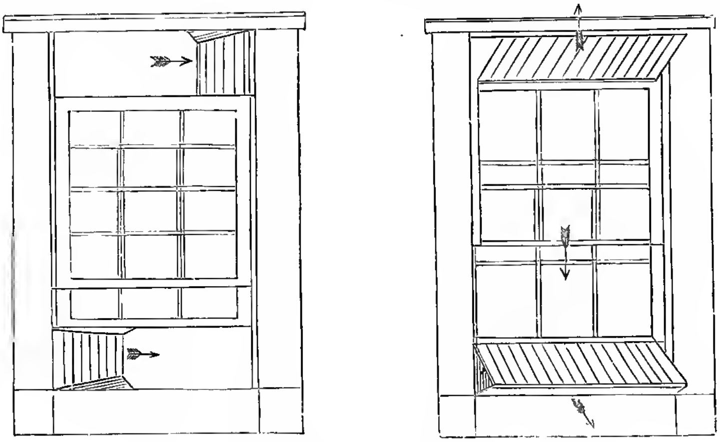

FIG. 32. FIG. 33.

Ventilation by means of windows.

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[1] Reid: Illustrations of the Theory and Practice of Ventilation, London, 1844.

tom of the window, as suggested by the essayist of the Massachusetts Medical Society, by which a current of air in and out at the window is created, is also an excellent idea, which may be applied in practice at very little expense. It is best illustrated by the accompanying cuts (Figs. 32 and 33). Various methods have been adopted in hospitals by which the upper portion of the sash, or a supplementary sash of about a foot in width, can be let down to an angle of 45°, and controlled by cords passing

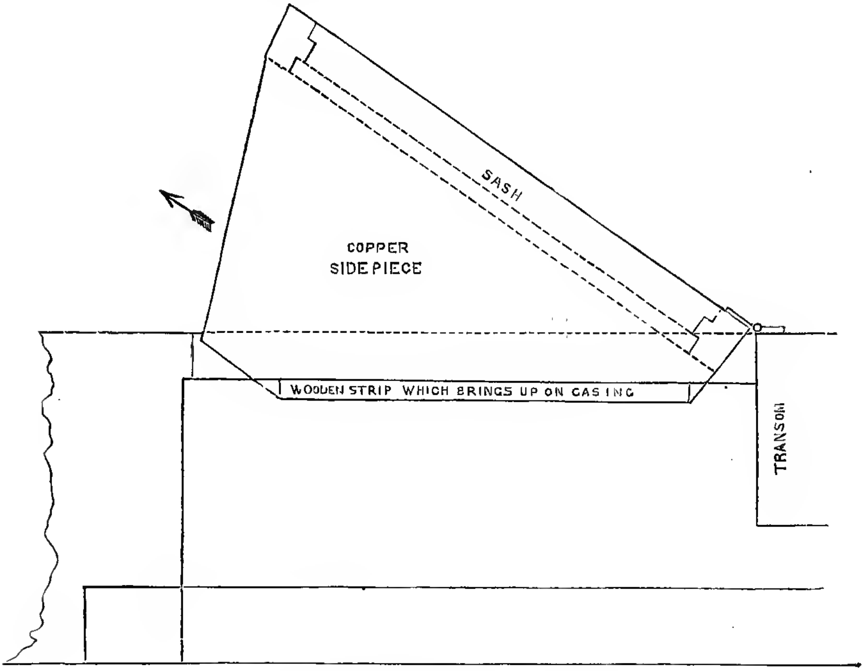


FIG. 34.—Folsom's transom window (open).

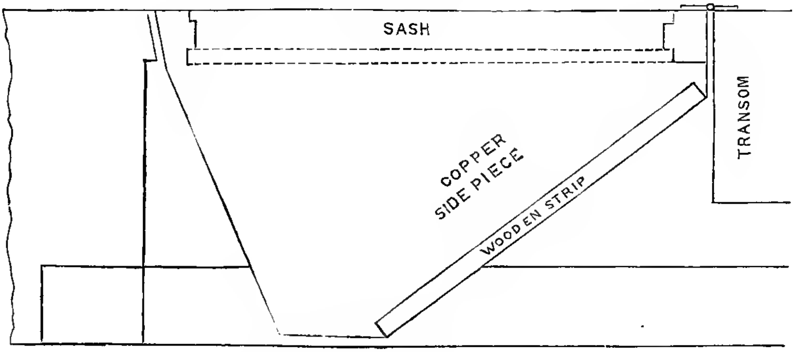
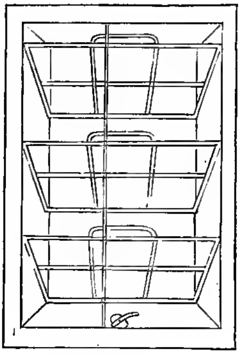


FIG. 35.—Folsom's transom window (shut).

down to a suitable distance from the floor. In this way the current of air is thrown up toward the ceiling, and does not incommode the inmates



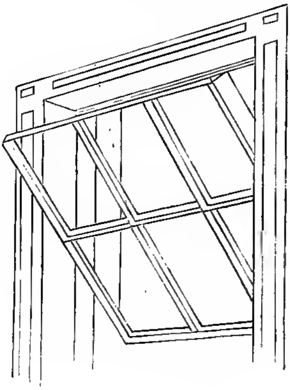


Fig. 36. Husson's windows. Fig. 37.

of the room. This is best shown in Folsom's transom window (Figs. 34 and 35), and in Figs. 36 and 37, copied from Husson.

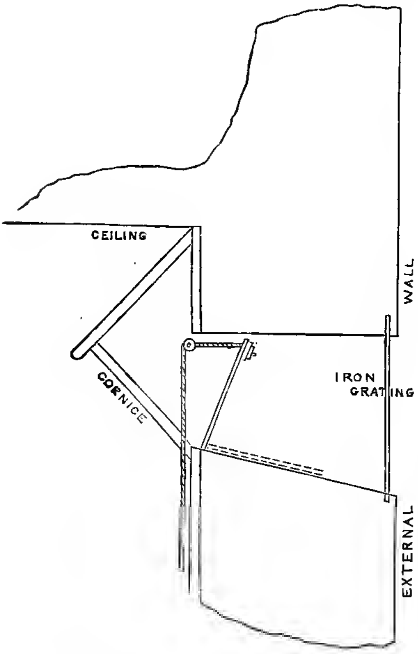


Fig. 38.—Plan of ventilator for room.

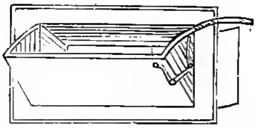


Fig. 39.—The Sherringham ventilator.

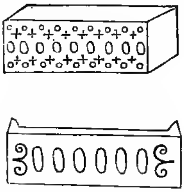


Fig. 40.—Jennings' air-bricks.

Ventilation by openings through the walls.—The method of ventilating by means of the windows may be supplemented by various means of direct communication with the external air. In the English report on barracks and hospitals, it is proposed that openings be made through the walls of the buildings, to communicate on the one hand with the external air or with air-spaces within the walls, and on the other with the wards, behind a perforated cornice.[1] (See Fig. 38.) The Sherringham ventilator (Fig. 39) supplies a ready method in a similar manner. Jennings' air-bricks are shown in Fig. 40. Arnott's chimney-valve (Fig. 41) furnishes openings into an air-shaft within the wall. It is protected by a flap of silk or gauze and a perforated sheet of zinc or a wire netting.

The system of ridge ventilation has been largely and successfully used in buildings of one story, the superstructure being freely open to the external air.[2] The louvre or opening at the top should be provided with shutters on either side, to be closed on the windward side.

A very simple plan, devised by Dr. J. B. Hamilton, Surgeon U. S. Marine Hospital Service, for the ventilation of a water-closet at the Marine Hospital at the port of Boston, has been found to work so well that mention is made of it. The wooden shaft AB, open at each end, is placed in an outer passage through which the air flows freely. With the wind from the direction A the air passes into the shaft and is discharged into the closed room at C. It is forced out at D, and, by the method of perflation, passes out at B. The action of the air, in the passage-way outside the shaft, also increases the outward current at B by the method of aspiration. With the wind in the direction BA, the current is reversed.

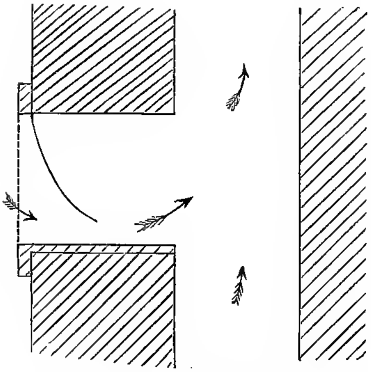


Fig. 41.—Arnott's chimney-valve.

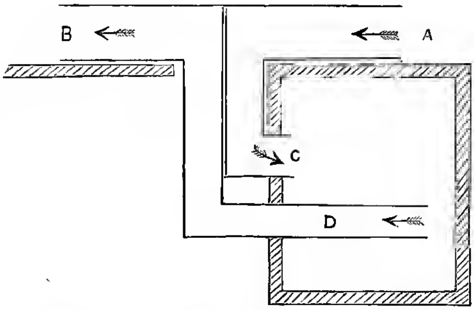


Fig. 42.—Hamilton's method of ventilating a closed room.

Openings for ventilation should be made both at the top and at the bottom of the room. It is an error to suppose that, because carbonic acid is heavy, the air rendered foul by respiration and combustion tends to descend to the floor. If carbonic acid were pure it would, as the simplest chemical experiment shows, be heavier than air; but, when diluted and

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[1] Report of Committee on Barracks and Hospitals.

[2] Hammond: A Treatise on Hygiene, Philadelphia, 1863.

heated, it mixes with the air and is only to be separated by the operation of chemistry or vegetable forces. In general, if the air to be admitted cannot be warmed, it should be admitted nine or ten feet from the floor and be directed upward; if warmed, at the bottom. Outlets, if heated or aspirated, can be at any point; if not heated, they should be at the top. It is only by a division of the ventilating means into small ducts that draughts can be avoided.

Draughts.—"The rate at which the movement becomes perceptible is much influenced by the temperature of the air; if this is about 70°, a very considerable velocity is not perceived. But, taking the temperature of 55° or 60° F., a rate of 1½ feet per second (=1 mile per hour nearly) is not perceived; a rate of 2 and 2½ feet per second (1.4 and 1.7 miles per hour) is imperceptible to some persons; 3 feet per second (2 miles per hour nearly) is perceptible to most; a rate of 3½ feet is perceived by all persons; any greater speed than this will give the sensation of draught, especially if the entering air be of a different temperature or moist."[1]

Ventilation by aspiration.—Next in importance to the method which secures ventilation by means of openings which communicate directly with the external air, is the method of extraction. The fireplace and the open stove first suggest themselves. The injunction bears repetition that all flues in hospital buildings should serve the double purpose of carrying off the smoke, etc., and aiding the ventilation. All smoke-stacks should be inclosed in ventilating shafts, having direct communication with the wards. Steam-pipes passing to upper stories may serve the same purpose, or, in place of either, a suitably arranged fire, or one or more gaslights in the upper part of the shaft, will furnish ascensional power. The gaslight may serve the additional purpose of lighting an upper hall or room. In large hospitals a powerful exhaust-power is derived from a tall chimney, to which ventilating pipes are conducted from the various parts of the institution. Fig. 43 shows the plan for ventilation suggested by Watson, and Fig. 44 that by Mackinwell. A plan is given by Reid, by which the

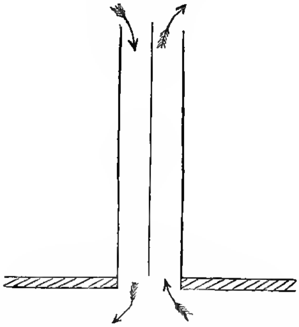

FIG. 43.—Watson's plan of ventilation.

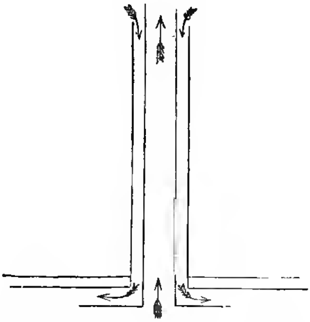

FIG. 44.—Mackinwell's plan of ventilation.

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[1] Parkes: Op. cit.

exhaust ventilators may be adapted to ornamental pillars or concealed within the walls.[1] The system of ventilators may be aided by the use of foul-air closets for each bed or for alternate beds, to be connected with the ventilating shafts; such accommodations may be used for spit-cups and chamber-vessels, which in this way are practically removed from the ward and yet at the same time remain within reach.

Still another method is that of utilizing the gas-burners of the ward in such a manner that the air supplied for combustion passes into the gas-fixture, and can then only escape by conduits directly into the chimney or into ventilating shafts. Figs. 45, 46, and 47 show different plans of accomplishing this.

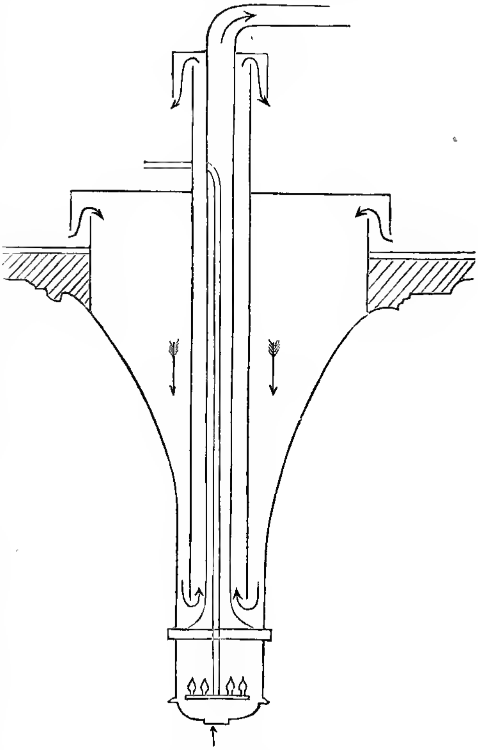

FIG. 45.—Gas ventilator.

In St. Luke's Hospital, in New York, a large chapel was constructed in the centre of the building, into which the wards on the two stories open directly by doors. The primary object of the chapel was to allow the patients, confined to their beds, to listen to the morning and evening religious services of the Episcopal Church. It was found, however, that this room acted as a vast ventilating flue, by which the air was drawn from the wards. This plan could only be made practically useful by keeping the windows of such central hall constantly open.

Galton recommends that one square inch of outlet be allowed for every fifty or sixty cubic feet of space; these proportions, however, should vary somewhat according to the extent of floor, and also to some extent according to the height of the room.[2] The barrack commissioners of 1861 order on an average eleven square inches of outlet for each man, and the area of the inlets is made nearly equal to that of the outlets; and, including the chimneys (for which they allow six inches to a man), the total of openings per head is about twenty-eight square inches per head. Parkes would make each individual inlet opening not larger than from forty-eight to sixty square inches, or enough for two or three men; and the

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[1] Reid: Op. cit.

Galton: Op. cit.

outlet not more than one square foot, or enough for six men. Distribution is more certain with these small openings.[1]

Ventilation by propulsion.—The method of ventilation by extraction is more nearly allied to the natural one, as the method by propulsion may more properly be called the artificial method. Practically the plans which depend solely on artificial means have failed. At the Lariboissière Hospital, which cost £100,000, a very beautiful and ingenious system of artificial ventilation is in use; but the wards are not sweet or healthy. At the York County (England) Hospital, soon after it was built, the chimneys were closed and a similar artificial system was adopted; but it was found to be ineffectual, and a return to more natural means was found to be necessary. At Guy's, Bristol, West Kent and Maidstone hospitals, and at the Liverpool Royal and Edinburgh infirmaries, artificial ventilation has been tried and abandoned. The extract from the views of Miss Nightingale, expressed in 1862 to the French Academy, on the sanitary state of the Lariboissière, epitomizes the faults of artificial and the advantages of natural ventilation. "The principle by which these gentlemen, MM. Guéneau de Mussy, Louis, Rayer, and Cloquet, were guided, was that of ventilation in as simple and perfect a manner as possible. This natural ventilation is now replaced by a very ingenious and expensive artificial ventilation. . . . Why not have courage, and introduce fireplaces, and air wards from without at the natural temperature? . . . . Regulated heat and regulated admission of fresh air, with shafts for removing foul air, would cure the Lariboissière; nothing else will . . . . The want of ventilation in the Lariboissière is the worst I ever met with . . . . Ventilation with warm air is a mistake . . . . While we are striving to

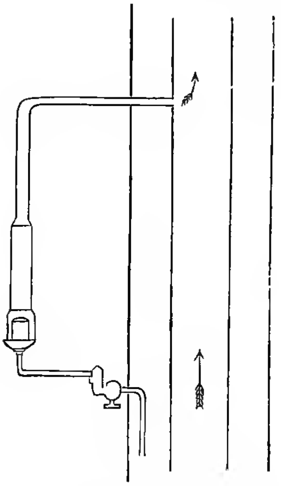

FIG. 46.—Gas-ventilator.

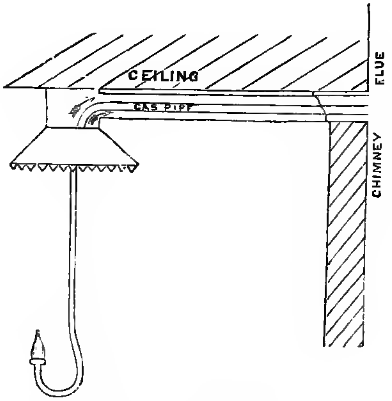

FIG. 47.—Gas-ventilator.

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[1] Parkes: Op. cit.

introduce and force upon England the pavilion construction for hospitals, which is derived from France, the French are forcing it into contempt by their abominable artificial ventilation."[1]

As the essence of the method by extraction is the exhaustion of the air of a room which is supplied by air rushing in through other inlets, so the system of propulsion is obtained by repletion with air which is left to escape as best it may. The propulsive power used at Lariboissière, at Beaujon, and the Hôpital Necker, is directed from a central shaft, and the air is distributed at various points where it is needed. The fan-blower has been adopted in many institutions, but the system is an expensive one, and has not been considered entirely successful. The fan is valuable for those cases, as in theatres and crowded assembly halls, where a large amount of air has to be suddenly and temporarily supplied. If the machinery breaks down, the ventilation stops.

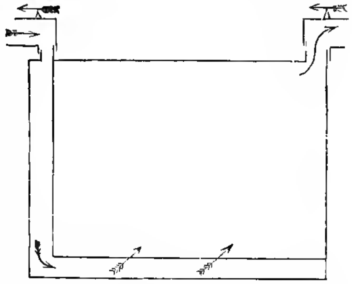

FIG. 48.—Egyptian mode of ventilation.

Dr. Van Hecke suggested supplying the air by the Archimedean screw;[2] Dr. Arnott by an air-pump and gasometer, with air-tubes extending to the point of exit.[3]

Parkes states that, in Egypt, the wind is allowed to blow in at the top of the building through large funnels (see Fig. 48). This method has been in use from time immemorial, and may be carried into effect by means of wind-sails or cowls at the top of descending flues (see Figs. 49 and 50).

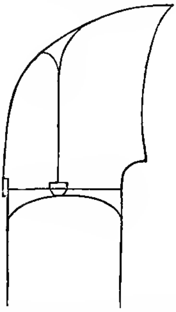

FIG. 49.—Reid's ventilating cowl.

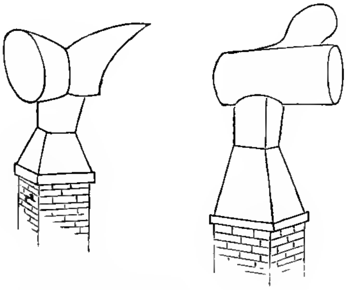

FIG. 50.—Different forms of cowls.

Combined methods of ventilation.—It has been found most desirable to combine various means of ventilation in the same building for the admission of pure air and the elimination of foul. It should be clearly understood that the air must be pure, that it must be warmed if too cold,

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[1] Shrimpton: The Crimean War. The British Army and Miss Nightingale, Paris, 1864.

[2] Report of Committee: Op. cit.

[3] Arnott: Art. "On the establishment of hospitals," London Med. Gazette, 1840.

and that it must be well distributed through the room, so as to be imperceptible, and so that all parts shall be well ventilated. The strictly natural means must never be wanting, and the various modified means should simply supplement them.

The objection may be raised that, with so many methods of ventilation in operation in the same building or apartment, the different systems will be very likely to militate against each other. However this may be, it may safely be assumed that no one system is perfect or will work well under all conditions of the atmosphere.

SECTION VIII.

WATER-SUPPLY.

The water-supply is, in most cities, obtained from municipal companies, and can be furnished in practically unlimited amounts. Parkes states that the amount of water taken by a healthy man is, on an average, from $\frac{1}{2}$ a fluid ounce to $\frac{6}{10}$ or $\frac{7}{10}$ of an ounce for each pound avoirdupois of body weight.[1] A man weighing 140 pounds will therefore take from 70 to 90 fluid ounces daily, and in ordinary diet about 20 to 30 ounces of this are taken in the solid food. This amount, however, will be considerably increased if the persons are engaged in employments requiring active exertion. The smallest amount for personal use, cleansing of clothes, and for the share of house-washing, is about 4 gallons per head daily. The supply required will be largely increased if water-closets and baths be used. In 1862, London received about 50 gallons per head daily; in 1857, the average supply to fourteen English towns of second-rate magnitude was 24 gallons. In 1878 fifteen American cities received an average of nearly 66 gallons per head daily. For hospitals, from 40 to 50 gallons daily is the least that should be used per bed.

Where other sources than an aqueduct must be depended on, careful attention is to be given to the character of the water, and especially to liability to contamination from water-closets or privies, cesspools, drainage from marshes or unhealthy localities.

Where it becomes necessary to store water in tanks, they should be made of slate, iron, or, if in the ground, of brick. Lead and zinc should never be used. The tanks should be covered in all cases, to prevent the absorption of impure air and to lessen evaporation. To meet the same end, they should be deep, rather than extended, and they should be so constructed that they can be frequently and readily inspected and cleansed.

The pipes for the distribution of water should be lined or so far protected as to prevent the immediate contact of the water with lead.

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[1] Parkes: Op. cit.

In most large institutions water is supplied through meters, a plan which is excellent in itself, if not watched so carefully as to prevent a due use of the water to meet the requirements of health.

The time will perhaps come when seaport cities will depend for their supply of water, for extinguishing fires and for similar purposes, on the ocean or harbor, so that, by a method resembling that known as the Holley system, salt water may be forced in unlimited supply through the principal avenues of the city. Under such circumstances the main might be tapped at a point near the hospital, and a supply of salt water be secured for cases where its use would be beneficial.

SECTION IX.

DRAINAGE.

No drain should pass under any part of a hospital, or, indeed, under any inhabited building, but should be conducted directly away from the walls into a common sewer. Drains should be trapped at the various points where water enters them—as, for example, at basins, bath-tubs, sinks, and water-closets as well as at some point outside of the building, before the large service-drains enter the common sewer. No better trap for basins, sinks, and urinals can be suggested than that of Col. Waring, a cut of which is given (Fig. 51). An undoubted source of danger in the ordinary trap lies in the fact that the water-seal being exposed to sewer-gas *under pressure* from below, absorbs sewer-gas, which it gives off at the natural density of the atmosphere above.

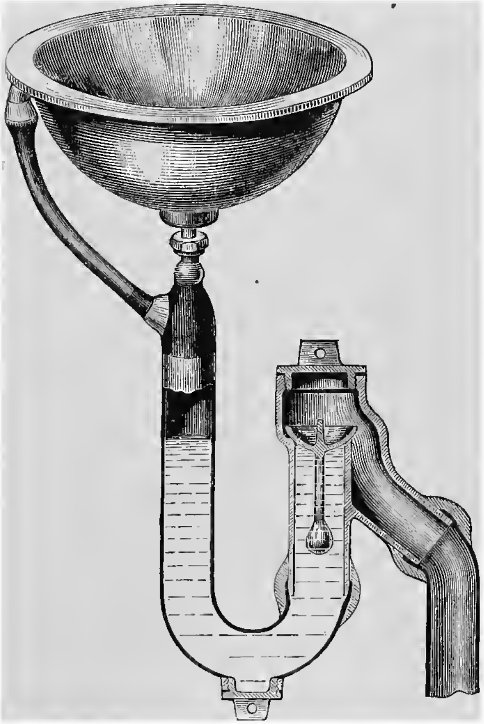

Fig. 51.—Waring's trap.

Ammonia has been found to produce its chemical effect at the house end of a trap within fifteen minutes after being introduced at the sewer end. Col. Waring's trap has not only the water-seal, but also a metal valve, which is claimed to be water-, steam-and gas-tight, and which allows the passage of water downward, but is a perfect protection against any return current coming from the opposite direction.

English architects—and it may well be conceded that the English are far in advance of us in sanitary architecture—recommend that drain-pipes discharge their contents outside the building, through an open pipe on a grating, and then through a flush trap into the sewer; but, if properly trapped and ventilated, a continuous drain seems preferable, and in cold climates the pouring out of the sewage on the open grate would be impracticable.

The smaller drain-pipes within the building may be of lead-pipe, of a size commensurate with the work to be accomplished; soil-pipes should always be of iron. The main drain-pipes, and especially the soil-pipes, must in all cases be carried above the roof, as a means of ventilation and to relieve pressure on the general drainage service. They should never be conducted within the ordinary ventilating shafts.

Drain-pipes and soil-pipes passing down through the building from upper stories should be enclosed in independent shafts, so arranged also that the pipes can be reached throughout their length for inspection and repair. In fact, in all institutions, all plumbing and pipes for the conveyance of water, either pure or foul, should be exposed. Drain-pipes and water-pipes should not be laid against outer walls or in any position exposed to frost.

SECTION X.

LIGHTING.

The wards of a hospital need not be supplied largely with means of lighting for use at night; but the necessary fixtures should be of the ventilating pattern, the gaslights being made to do the double duty of illumination and ventilation. The patterns of gaslights furnished by Messrs. Storms & Son, Southwark Bridge Road, London, and by other English manufacturers, seem to meet every requirement. Simpler devices, which combine the same ideas, may be adopted (Figs. 45, 46, and 47). The lights for the service-rooms and the administrative department may be the same as commonly used in dwellings.

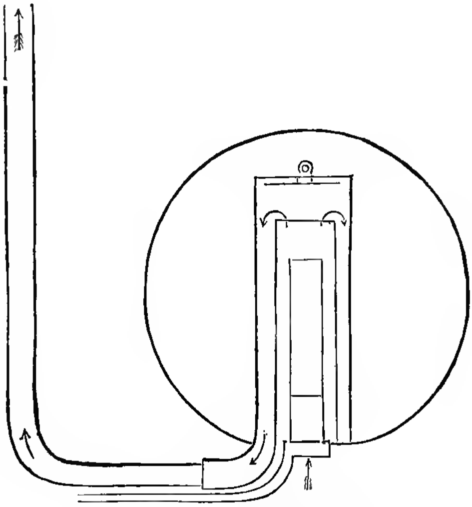

FIG. 52.—Ventilating gas-fixture.

SECTION XI.

COTTAGE HOSPITALS.

No treatise on hospital construction at this day can be complete without reference to cottage or village hospitals. Though comparatively unknown in this country, they are taking a prominent place in the economy of English country life.

Dr. George Derby, in his report to the Massachusetts State Board of Health for 1874, says: "There are many reasons for believing that, at the present time, small and well-arranged hospitals in at least twenty of our busy towns would be the means of saving life, and of preventing useless suffering to both the sick and the well."[1]

The system of village hospitals, if rightly understood, would be gladly welcomed by medical men practising in their neighborhood, as furnishing a ready means for the treatment of various classes of patients; for instance, those who cannot be properly cared for in their homes, and cases of accident requiring immediate treatment or operation and subsequent skilled attendance and nursing. Such hospitals should be open for practice to all the reputable physicians of the town, although the immediate care of

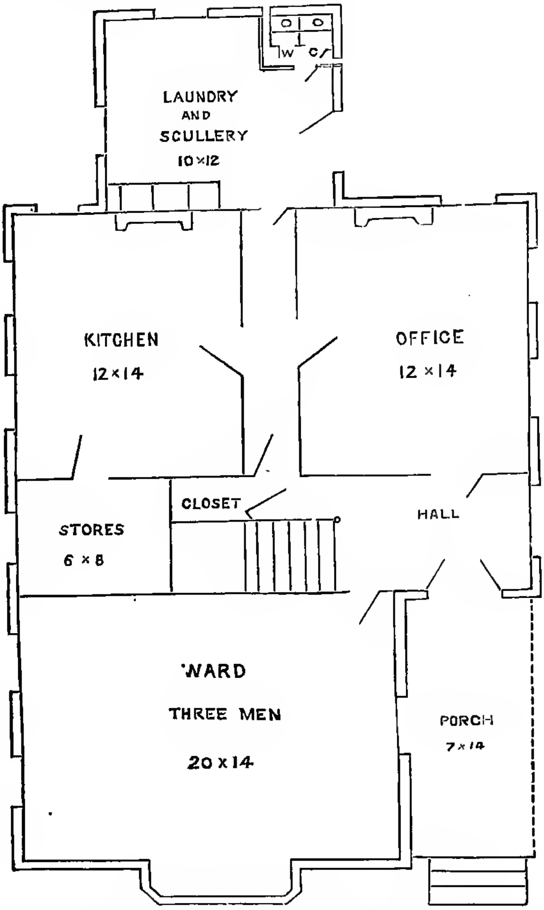

FIG. 53.—Cottage hospital.—Plan of ground floor.

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[1] Report of State (Mass.) Board of Health for 1873, Boston, 1874.

the institution should be under the control of one judicious medical officer.

It should not be considered that the establishment of a village hospital necessitates gratuitous attendance on its patients. It should be understood that the tax-payers of the town provide a building, in which their own people, under circumstances which may happen to any one of them, can be more satisfactorily attended than in their own homes, while the professional fees of the physicians might remain the same.

The country practitioner, with such means at hand and aided by one or two trained nurses, would have the advantages now enjoyed only by metropolitan physicians, and would be enabled to keep his patient under his eye, within easy distance of his own home. The patient too would have the familiar faces of friends and neighbors about him, and could breathe his own pure country air. "The opportunity of giving this frequent attention is lost when the patient lives at a distance from a medical man, whose daily work is too often represented by forty or fifty miles of travelling a day."[1]

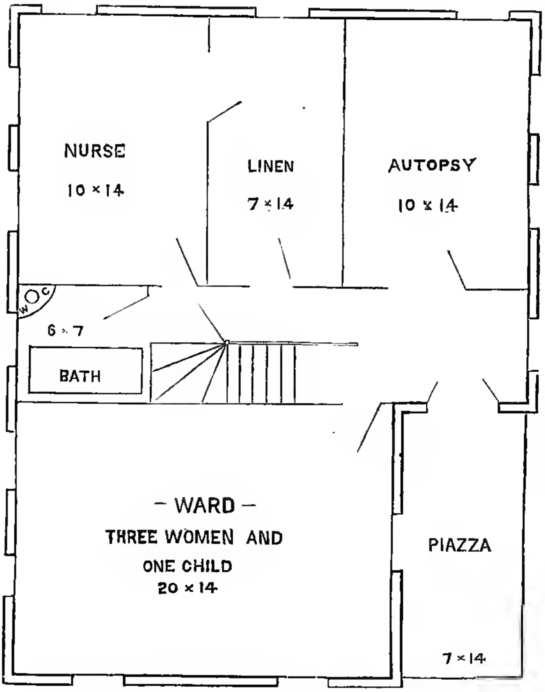

Fig. 54.—Cottage hospital.—Plan of second floor.

The hospital organized by Mr. Napper, in Cranleigh, England, in 1859, and that by Mr. Davis about the same time, were the pioneers of

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[1] Swete: Handy-Book of Cottage Hospitals, London, 1870.

at least sixty (1870) scattered throughout the British Islands. Simplicity and inexpensiveness should be the first considerations in the arrangement of cottage hospitals. It is not intended in the smaller institutions of this class to imitate in any way the form or the details of a general hospital, with its wards, nurse-rooms, etc. A plain country-house, of moderate size, possessing the advantages of healthy situation, with a southern exposure, plenty of sunlight, good drainage, and a reasonable amount of ventilation, will answer all the purposes of such a village hospital. One or two beds to one thousand of the population, or a larger proportion in manufacturing districts, should be provided. Five or six beds would be ample for many of our country towns. In addition there should be a good kitchen, a sitting-room, office or living-room, and a covered veranda on the sunny side. The height of ceiling, the water-supply, the means of ventilation and heating, the bath-room, water-closet, and other details, a mortuary-room, where a coroner's inquest may be held or a post-mortem examination made, a plot of ground where convalescents may enjoy a sun-bath and fresh air—all these are subjects which would call for attention in the establishment of a village hospital. Common sense views are equally necessary in small as in large hospitals, whether in town or country. A simple plan for a village hospital is given in Figs. 53 and 54. If it is found necessary to provide for a larger number than six or eight, the best plan would be to construct one or more pavilions, in addition to the hospital proper, which would then serve as the administrative department and for the accommodation of attendants.

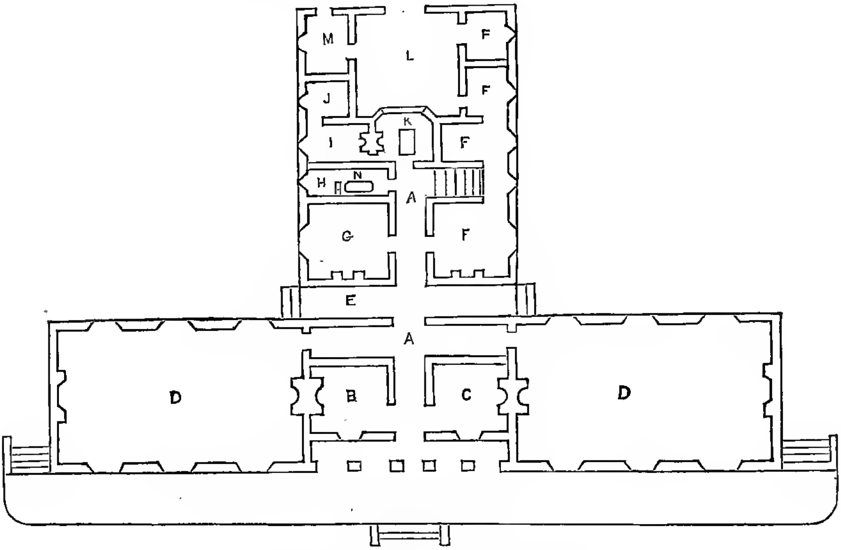

Fig. 55.—Plan of larger cottage hospital.

A plan for a larger cottage hospital is given in Fig. 55; it is a modification of one figured in Swete's Handy-Book of Cottage Hospitals, in which A might represent hall and passages, B matron's room, C reception and manager's room, D wards for six patients each, E balconies, F kitchen and annexes, G day-room and dining-room, H water-closet, I special ward, adjoining K operating-room, J surgical apparatus, L area, M mortuary, N bath-room. Additional rooms for private patients and attendants may be provided over B, C, G, F, etc.

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